MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XCI. FEBRUARY 13, 1931. No. 4

ANNUAL GENERAL MEETING.

Dr. A. C. D. CROMMELIN, President, in the Chair.

The Minutes of the preceding Annual General Meeting were read and confirmed.

The President referred to the death of Sir Charles Parsons, who had been a great benefactor to the Society.

A message of congratulation from the Fellows assembled was sent to Mr. Richard Inwards, who had just completed his seventieth year of Fellowship of the Society.

Dr. W. H. Steavenson reported on the instruments in the possession of the Society which he had examined at the request of the Council, and it was resolved that the Council be empowered to deal with the instruments in accordance with the suggestions contained in the Report (see p. 310).

It was resolved that the date for returning library books in each year be altered from the second Friday in *November* to the second Friday in *June*, and that Library Regulation VII. be accordingly amended to read as follows :—

VII. All books must be actually returned to the Library on or before the second Friday in June in each year, and not taken out again till the following Friday without special permission. It shall be the duty of the Assistant-Secretary, before the June meeting, to forward to all Fellows of the Society who, according to the entries in the book

kept for that purpose, have any books belonging to the Society in their possession, a letter requesting that all such books be returned to the Society on or before the day of the June meeting.

The Report of the Auditors of the Treasurer's accounts for the year 1930 was read and discussed. The Report is given on p. 309.

The Annual Report of the Council was partly read.

The Address on the award of the Gold Medal was delivered by the President, after which the Gold Medal was handed to the Netherlands Minister, Jonkheer Dr. R. de Marees van Swinderen, for transmission to Professor W. de Sitter, to whom it had been awarded for his theoretical investigations on the orbits of the satellites of Jupiter and his contributions to the theory of relativity (see p. 422).

The President then delivered an Address on the award of the Jackson-Gwilt Medal and Gift, after which the Medal was handed to the Foreign Secretary for transmission to Mr. Clyde W. Tombaugh, to whom it had been awarded for his discovery of the extra-Neptunian planet Pluto (see p. 434).

The President having appointed the Scrutineers, the Society proceeded to the ballot for Officers and Council for the ensuing year. The names of those elected are given on p 438.

During an interval Dr. L. J. Comrie gave an account of the New Zealand eclipse expedition to Niuafou in 1930, and Professor Stratton spoke on M. Lyot's success in detecting the corona without an eclipse.

The thanks of the Meeting were given to the retiring Members of Council, and also to the Auditors of the Treasurer's accounts, and to the Scrutineers of the ballot.

The election by the Council of the following Fellows was duly confirmed:—

Geoffrey Hamer Bairstow, Ardengair, 121 Home Park Road, Wimbledon, London, S.W. 19.

I. James Bews, 151 Earl Street, Scotstoun, Glasgow.

Roger Daniel Hewart Jones, B.A., Eryl Daf, Radyr, near Cardiff; and

Julie Marie Vinter Hansen, M.Sc., University Observatory, Östervald, 3, Copenhagen.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Paul Adrien Maurice Dirac, Ph.D., F.R.S., St. John's College, Cambridge (proposed by Harold Jeffreys) ;

Captain James Ritchie Frost, Dockmaster, Tilbury Docks, 2 The Gardens, Tilbury, Essex (proposed by F. D. Addyman) ;

John Watson Maccoll, B.Sc., Ph.D., Ordnance Committee, Woolwich, London, S.E. 18 (proposed by G. T. Walker) ;

G. C. McVittie, M.A., Ph.D., Department of Mathematics, The University, Leeds (proposed by R. Stoneley) ;

H. W. Owston, Heath View Hotel, 15 and 16 Montpelier Row, Blackheath, London, S.E. 3 (proposed by Knut Lundmark) ;

Abdel-Hamid Mahmoud Samaha, Assistant Astronomer, Helwan Observatory, Egypt (proposed by P. A. Curry) ; and

Joe Ueta, D.Sc., Assistant Professor of Astronomy, Kyoto Imperial University, Kyoto University Observatory, Kyoto, Japan (proposed by F. W. Dyson).

The following election, announced 1930 April 11, is void :—

Henry Major Twiselton, M.A., 2 Aldworth Grove, London, S.E. 13.

Report of the Council to the Hundred and Eleventh Annual General Meeting of the Society.

Progress and Present State of the Society.

	Patron	Institutional Members	Honorary Member	Fellows: Compounders	Fellows: Annual Subscribers	Associates	Total
1929 December 31	1	3	1	220	678	47	950
Since elected	...	...	...	+2	+56	+2	...
Deceased	...	...	...	−5	− 9	−1	...
Resigned	...	...	...	...	−16	...	...
Since compounded	...	...	...	+4	− 4	...	...
Restored to List	...	...	...	...	+ 1	...	...
Removed from list	...	...	...	...	− 7	...	...
1930 December 31	1	3	1	221	699	48	973

(Five Associates are also Fellows, and are therefore counted twice in the above table.)

RECEIVED.

	£ s. d.	£ s. d.
Balances, 1930 January 1:—		
In hand of Assistant Secretary on Petty Cash Account	17 17 0	
At Bankers', on Current Account	1025 11 4	
At Bankers', on Deposit Account (including Special Fund, £223, 6s. 0d.)	398 16 7	
At Bankers', on "C" Account (Trust Funds) ...	86 15 4	
		1529 0 3
Received on account of Dividends:—		
£1250 Metropolitan 3% Stock	37 10 0	
£2000 Swansea Corporation 3½% Stock	70 0 0	
£2287, 6s. 9d. East Indian Railway 3% Stock ...	53 11 10	
£5125 London, Midland and Scottish Railway 4% Debenture Stock	161 8 9	
£750 London, Midland and Scottish Railway 4% Consolidated Preference Stock	23 12 6	
£2400 Gas Light & Coke Co. 3% Debenture Stock ...	56 14 0	
£2000 Commercial Gas Co. 3% Debenture Stock ...	46 10 0	
£4877, 12s. 6d. War Loan Inscribed 5% Stock ...	243 17 6	
£419, 17s. 11d. Conversion Loan 4½% Stock, 1940/44	18 17 10	
£695, 16s. Conversion Loan 3½% Stock, 1961 ...	24 7 0	
Interest on Deposit Account	9 5 4	
Income Tax refunded, 1929 April–1930 April ...	89 0 3	
	834 15 0	
Sales of Publications £387 9 5		
Reprints 56 1 0		
	443 10 5	
Sales of Photographs	70 1 0	
Miscellaneous Receipts:—		
London Mathematical Society, expenses of Meetings, etc. £30 0 0		
Assist. Sec. and Clerk, Pension Premiums 19 5 0		
Sale of Cupboard, Books, and Waste Paper 22 8 2		
Postages repaid, and Use of Telephone 4 19 3		
Repayment of Balance of Guarantee, Institute of Physics 3 10 0		
Donation to General Fund 1 1 0	81 3 5	
		1429 9 10
Received on account of Subscriptions:—		
558½ Annual Contributions (including 3 Institutional Membership fees)	1172 17 0	
21½ Annual Contributions 1931, paid in advance (less 1s.)	45 2 0	
53 Admission Fees	111 6 0	
52 First Contributions	103 19 0	
1 Completion of First Contribution, part paid in advance in 1929	1 4 0	
Arrears paid off:—		
10 for 1928 ... ... £21 0 0		
46 for 1929 ... ... 96 12 0	117 12 0	
		1552 0 0
Compositions		122 17 0
Donation to Special Fund		2 2 0
Trust Fund Dividends:—		
£1212, 13s. 3d. East Indian Railway 3% Stock ...	28 8 8	
£542, 18s. 2d. India 3½% Stock	19 0 0	
£1934, 10s. 2d. 5% War Stock, 1929/47	96 14 6	
Income Tax refunded, 1929 April–1930 April ..	7 5 6	
Refund to Trust Funds from General Account, for Cheque Book debited 1929	0 16 8	
		152 5 4
		£4787 14 5

Examined and found correct.

(Signed) W. M. WITCHELL.
1931 *January* 23. A. J. THOMPSON.

PAID.

	£	s.	d.	£	s.	d.
Assistant Secretary: Salary	250	0	0			
Clerk: Salary	175	0	0			
Assistant Secretary and Clerk for work done for London Mathematical Society in 1929	10	0	0			
Extra Library Assistance	12	0	0			
Pension Premiums for Assistant Secretary and Clerk ...	57	15	0			
Porter and Wife: Wages	154	6	6			
Health and Unemployment Insurance	6	19	11			
Pension, Mrs. Barrett	32	10	0	698	11	5
Licence for Porter	0	15	0			
Fire and Accident Insurance	15	15	3			
Telephone	13	0	4			
Telegraphic Address and Time Signal	7	2	8			
Water Rate	12	17	3	49	10	6
Postage and Packing (including postage of *Monthly Notices*, etc., £91, 18s. 9d.)	147	4	10			
Telegrams	10	18	9	158	3	7
Printing, etc.:—						
Monthly Notices (Vol. 90, Nos. 1–9)	965	17	0			
Geophysical Supplements (Vol. 2, Nos. 5, 6)	78	9	0			
Memoirs (Vol. 65, pt. 1)	44	3	4			
Reprints	101	12	3			
Miscellaneous	59	4	4			
Photo-engraving:—						
Monthly Notices £46 17 5						
Geophysical Supplements 2 13 0	49	10	5	1298	16	4
Reproduction of Photographs for sale				53	12	0
Stationery and Office Expenses	22	3	7			
Library Equipment and Binding	39	16	0			
Subscription to International Telegrams Bureau, 1930–31	8	7	5			
Coal, Gas, Electric Light, Firewood	82	6	7			
House Expenses and Laundry	30	9	8			
Repair of Harrison Clock (completion)	15	0	0			
Fittings and Repairs	50	17	9			
Decoration of Society's Premises	407	0	3			
Ladies' Cloakroom	208	0	0			
Fire Escape	10	14	6			
Legal Charges	13	17	4			
Subscription to Committee on Library Co-operation ...	1	1	0			
Miscellaneous Expenditure	14	18	11			
Expenses of R.A.S. Meetings and Committees	17	19	10			
Expenses of Geophysical Meetings	6	6	11			
Expenses of L.M.S. Meetings	5	18	4			
Bank Charges and Cheque-Books	2	8	4			
Refund to Trust Funds for Cheque-Book debited 1929 ...	0	16	8			
				938	3	1
				3196	16	11
Purchase of £500 5% War Stock 1929/47 (General Fund)				508	17	0
Expenditure on Trust Accounts:—						
George Darwin Lecture	50	0	0			
Turnor and Horrocks Fund } Library ...	19	12	7			
Harry Watson Fund ... }	39	4	6			
Lee and Janson Fund	10	0	0	118	17	1
Balances, 1930 December 31:—						
In hand of Assistant Secretary on Petty Cash Account	7	6	11			
At Bankers', on Current Account	360	2	4			
At Bankers', on Deposit Account	475	10	7			
At Bankers', on "C" Account (Trust Funds) ...	120	3	7			
				963	3	5
				£4787	14	5

REVENUE

	£	s.	d.	£	s.	d.
To General Expenditure as per Cash Account	3196	16	11			
,, Reserve for Accounts due but not presented	305	0	0			
	3501	16	11			
Less Reserve for Accounts due 1929 now written back	290	0	0			
				3211	16	11
,, Amount transferred to Composition Fees Reserve Fund in 1930				122	17	0
,, 17 Annual Contributions in Arrear written off ...	35	14	0			
,, 10 Annual Contributions 1930 written off as per contra	21	0	0			
				56	14	0
,, Due for Publications, 1929, written off				0	1	1
Excess of Revenue over Expenditure, 1930				58	17	0
				£3450	6	0

Examined and found correct.

(Signed) W. M. WITCHELL.
A. J. THOMPSON.

1931 *January* 23.

ACCOUNT, 1930.

		£	s.	d.	£	s.	d.
By Subscriptions—							
558½	Annual Contributions (including 3 Institutional Membership Fees)	1172	17	0			
23½	ditto, paid in advance in 1928 and 1929 and now matured	49	7	0			
77	ditto, outstanding	161	14	0			
10	Contributions for 1930 due, but unpaid, in respect of Fellows died, resigned, or names removed, and written off per contra ...	21	0	0			
4	Annual Contributions for 1929 not previously brought into Account, received in 1930 ...	8	8	0			
					1413	6	0
,, 47	First Contributions, 1930, at 2 guineas ...	98	14	0			
1	ditto, partly paid in 1929 and now matured	0	18	0			
	ditto, completion of the above, paid in 1930	1	4	0			
5	ditto, at 1 guinea	5	5	0			
3	ditto, outstanding	3	3	0			
56					109	4	0
,, 53	Admission Fees, 1930	111	6	0			
1	ditto, paid in advance in 1929 and now matured	2	2	0			
3	ditto, outstanding	6	6	0			
57					119	14	0
,, 3	Composition Fees at 30 guineas	94	10	0			
3	ditto, reduced	28	7	0			
6					122	17	0
,, 6 per cent. of Composition Fees Reserve Fund as per Balance Sheet, transferred to Current Revenue				16	9	10
,, Sundry Debtors, 1930				54	10	9
,, Dividends, Sales of Publications and Photographs, and Miscellaneous Receipts, as per Cash Account		1429	9	10			
Less	Payments due 1928 and 1929 (£14, 2s. 11d., *less* 1/1 written off and 18/10 still outstanding) £13 3 0						
	Advance payments for *Monthly Notices*, Vol. 91 ... ... 79 4 0						
	Income Tax 1929 April–December, refunded in 1930 ... ... 54 17 8						
		147	4	8			
					1282	5	2
,, Payments for *Monthly Notices*, Vol. 90, Nos. 2–9, received in 1929 and now matured					41	5	4
,, Income Tax (General Fund) deducted at source 1930 April 6 to December 31, not yet refunded					59	12	8
,, Amount transferred from Special Fund to General Account to meet Current Expenditure					231	1	3
					£3450	6	0

BALANCE SHEET,

LIABILITIES.

	£ s. d.	£ s. d.
22½ Subscriptions for 1931 (less 1/-), paid in 1928 and 1930		47 4 0
Sundry Creditors for Accounts due but not presented ...		305 0 0
Cash Balances (Income) of Trust Funds—		
Turnor and Horrocks Fund	6 10 1	
Harry Watson Fund	37 14 3	
Lee and Janson Fund	16 12 5	
Hannah Jackson Fund	35 4 7	
George Darwin Lectureship Fund	24 2 3	
		120 3 7
Trust Funds (Capital), as per contra		2,949 17 0
Income Tax on Trust Funds, 1930 April 6–December 31, not yet refunded, as per contra		6 2 7
Special Fund—		
As at 1929 December 31	1,680 12 5	
Donation in 1930	2 2 0	
Income Tax 1926–27 refunded from General Account	5 13 3	
	1,688 7 8	
Less transferred to General Account, 1930	231 1 3	
		1,457 6 5
Composition Fees Reserve Fund :—		
As at 1929 December 31	152 0 0	
Received in 1930	122 17 0	
	274 17 0	
Less 6 per cent. transferred to current revenue ...	16 9 10	
		258 7 2
Advance Payments for *Monthly Notices*, Vol. 91		79 4 0
General Fund—		
As at 1929 December 31	15,923 15 11	
Add Excess of Revenue over Expenditure, 1930 ...	58 17 0	
		15,982 12 11
		£21,205 17 8

Examined and found correct.

(Signed) W. M. Witchell.

A. J. Thompson.

1931 *January* 26.

1930 *December* 31.

ASSETS.

	£ s. d.	£ s. d.
Sundry Debtors for Subscriptions in Arrears—		
23 for 1929	48 6 0	
77 for 1930	161 14 0	
3 First Contributions, 1930, outstanding	3 3 0	
3 Admission Fees, 1930, outstanding	6 6 0	
		219 9 0
Sundry Debtors, 1929		0 18 10
Sundry Debtors, 1930—		
Due for Publications and Reprints	53 16 9	
Due for Photographs	0 13 0	
Due for Postages	0 1 0	
		54 10 9
Investments, General Fund—		
As at 1929 December 31, valued as on 1922 December 29	14,986 0 0	
Purchase (1930), of £500 5 per cent. War Stock, 1929–47	508 17 0	
		15,494 17 0
Investments of Special Fund, valued as at date of purchase—		
£695, 16s. Conversion Loan 3½ per cent. 1961 ...	525 0 0	
£419, 17s 11d. Conversion Loan 4½ per cent. 1940–44	400 0 0	
£525 War Stock 5 per cent. 1929–47	532 6 5	
		1,457 6 5
Investments of Trust Funds, valued as on 1922 December 29 or date of purchase if later ...		2,949 17 0
Income Tax 1930 April 6–December 31, not yet refunded—		
General Fund	59 12 8	
Trust Funds	6 2 7	
		65 15 3
Sundry Balances—		
In hand of Assistant Secretary on Petty Cash Account	7 6 11	
At Bankers', on Current Account	360 2 4	
At Bankers', on Deposit Account	475 10 7	
At Bankers', on "C" Account (Trust Funds) ...	120 3 7	
		963 3 5
		£21,205 17 8

Astronomical and other Manuscripts, Books, Prints, Photographs, and Instruments.

Furniture, etc.

Stock of Publications and Photographs for sale.

Five Bronze (Jackson-Gwilt) Medals.

INVESTMENTS.

As at 1930 December 31.

GENERAL FUND.

£1250 Metropolitan 3-per-cent. Stock.

£2000 Swansea Corporation 3½-per-cent. Stock.

£2287, 6s. 9d. East Indian Railway 3-per-cent. Debenture Stock.*

£5125 London, Midland and Scottish Railway 4-per-cent. Debenture Stock.*

£750 London, Midland and Scottish Railway 4-per-cent. Consolidated Preference Stock.*

£2400 Gas Light and Coke Co. 3-per-cent. Debenture Stock.*

£2000 Commercial Gas Co. 3-per-cent. Debenture Stock.*

£4352, 12s. 6d. 5-per-cent. War Loan Inscribed Stock, 1929–47.

GROVE-HILLS SPECIAL FUND.

£525 5-per-cent. War Loan Inscribed Stock, 1929–47.

£419, 17s. 11d. Conversion Loan 4½-per-cent., 1940–44.*

£695, 16s. Conversion Loan 3½-per-cent., 1961.

FIVE TRUST FUNDS.

£1212, 13s. 3d. East Indian Railway 3-per-cent. Stock.*

£542, 18s. 2d. India 3½-per-cent. Stock.

£1934, 10s. 2d. 5-per-cent. War Loan Inscribed Stock, 1929–47.

* Taxed at source.

Report of the Auditors for the Year 1930.

We have examined the Treasurer's account of receipts and expenditure, and the Revenue Account and Balance Sheet, for the calendar year 1930, and have certified them to be correct. The investment holdings have been certified respectively by the Bank of England or by the Westminster Bank, and are in accordance with the printed list.

The amount of 5 per cent. War Stock held to the account of the General Fund has been increased by £500 since the last Report.

The sum held in reserve for Compositions under the arrangement described in an appendix to the Auditors' Report for 1929 is £258, 7s. 2d., representing a net increase of £106, 7s. 2d. The sums at present transferred to this Reserve are those actually paid in composition of annual subscriptions ; but if admission fees be regarded as paid by new Fellows for the purchase of rights in the existing property of the Society, it would seem that admission fees might also be put to reserve on analogous grounds.

The question of a separate investment of the funds in the Compositions Reserve is, in our opinion, a matter for early consideration.

Among the items of general expenditure to which attention may be directed, the most important is the sum spent in redecorating the Society's Rooms. The necessity for an item of this character arises at irregular intervals averaging about twelve years. On the present occasion an unusually long interval had elapsed, and the work necessary was correspondingly heavy. In addition, the opportunity was taken to instal cloakroom accommodation for the lady Fellows of the Society.

Notwithstanding the exceptional demands on the Society's funds entailed by these extensive works, the Revenue Account shows a small excess of income over expenditure for the year. This, however, was only made possible by the ability of the Council to transfer to current revenue the uninvested money standing to the credit of the Special Fund. By a resolution of the Council in 1928, the income from the *invested* portion of the Special Fund is now merged in general revenue. Consequently no further accumulation may be looked for from this source.

It should be noted that the past year is the first complete year in which the sale of the Society's publications has been conducted wholly from the Society's rooms. A valuable addition to the revenue accrues from the commission thereby saved.

The decision of the Council to revert to the former practice of supplying free to authors a certain number of reprints of papers has affected " miscellaneous receipts " proportionately.

The cessation in October of the pension paid to the widow of the late porter, consequent upon her attaining the age at which a state pension is payable, will relieve the funds of a definite charge in future years.

By an oversight, the number of subscriptions outstanding for the year 1929 was stated in the last Report to be 75 instead of 78. The three subscriptions overlooked were in fact paid on 1930 January 1, and have been brought into the 1930 Revenue Account together with one

other subscription in respect of a Fellow restored to the list in 1930, by resolution of the Council, on payment of his 1929 subscription.

A list has been laid on the table containing the names of those Fellows in arrear for sums due on 1930 January 1, with the amount due against each Fellow's name.

The books, instruments, and other effects on the premises appear to be in satisfactory order. A welcome addition to the property of the Society since the last Report is the bronze statuette of Sir Isaac Newton —modelled from the well-known statue at Trinity College, Cambridge (Roubilliac's)—which was kindly presented to the Society by Rev. M. P. M. M'Lean.

The checking of the books on the shelves of the library has been completed, and has revealed no further instance of volumes missing and unaccounted for beyond the seven described in last year's Report. It is regrettable that the publicity then given has not so far resulted in the return of any of the missing books.

It is a pleasure to acknowledge our indebtedness to the Assistant Secretary for the facilities accorded to us during the audit.

(Signed) W. M. Witchell.
A. J. Thompson.

1931 *February* 5.

Report on the Society's Instruments.

I have examined the instruments (about 130 in number) which are at present in the Society's apartments.

With a few exceptions they appear to be in fair or good condition. On the other hand, it is very noticeable that there is scarcely a single first-class modern instrument in the entire collection. A few of the older instruments are of definite historical interest; but the great majority are of an obsolete type, without being old or rare enough to be considered as valuable antiques. In their present positions they appear to serve no useful purpose whatever, and many of them have evidently lain untouched and unseen in their cases for periods between 50 and 100 years. Meanwhile they are, of course, occupying valuable space in the rooms of the Society. It therefore seems that, at least in the case of these less useful and valuable articles, the time has come for a general clearance on a drastic scale, with the double purpose of (*a*) relieving congestion in the Society's apartments, and (*b*) transferring the instruments to some situation where they may find some use, or at least be available for public inspection.

To this end I have ventured to make a rough preliminary classification of the instruments in the Society's collection, according to the following scheme:

I. Instruments to be retained in the Society's possession and *on its premises*, either for use there (*e.g.* Harrison Clock, Spitta thermometer, etc.), or to be available for loan to Fellows. These include all

instruments capable of being used for any practical modern purpose, including eclipse work, and therefore liable to be asked for by Fellows.

II. Instruments to be retained in the Society's *possession*, but to be *loaned* to Museums. These include the instruments that are valuable either historically or, on account of their fine condition, as specimens of early optical and mechanical workmanship.

III. Instruments to be *given* to Museums. These, while not being individually of great value, would be useful in illustrating the history of instrument-making.

IV. Instruments to be *given* to schools, laboratories, or other suitable educational institutions. (*N.B.*—Many of the instruments might be more particularly useful to schools where navigation is taught.)

V. Instruments to be offered as gifts to small astronomical societies.

VI. Instruments to be thrown away or otherwise disposed of as completely useless. W. H. S.

Gifts to the General Funds and Property of the Society.

The John Lee Gift : In 1836 John Lee, Esq., LL.D., gave the Advowson of the living of Hartwell ; in 1844 he gave the Advowson of the living of Stone, Bucks. In 1879 these Advowsons were repurchased by his heir, Edward Lee, Esq., for £700.

The Lawson Bequest (1856) : Henry Lawson, Esq., bequeathed to the Society the sum of £200, free of legacy duty.

The Carrington Bequest (1876) : R. C. Carrington, Esq., F.R.S., bequeathed to the Society £2000 Consols.

The Lambert Bequest (1877) : C. J. Lambert, Esq., presented to the Society the sum of £500, free of legacy duty, being part of a sum of money bequeathed by his father, Charles Lambert, Esq., for scientific purposes.

The McClean Bequest (1905) : Frank McClean, Esq., LL.D., F.R.S., bequeathed to the Society the sum of £2000, free of legacy duty.

The Farrar Bequest (1906) : The Rev. A. S. Farrar, D.D., bequeathed to the Society the sum of £100, free of legacy duty.

The Parsons Gift (1922) : The Hon. Sir Charles Parsons, K.C.B., F.R.S., gave to the Society £2500 War Stock (1929-47), in memory of his father, the 3rd Earl of Rosse, who made the 6-foot Reflector, and who died 1867 October 32.

The Grove-Hills Bequest (1922) : Colonel E. H. Grove-Hills, C.M.G., F.R.S., bequeathed to the Society, free of legacy duty, his collection of early Astronomical and Mathematical books up to the year 1700, together with a sum of £250 to cover the expenses incurred by the Society in connection with the books.

The Grove-Hills Special Fund: In 1923 the then Treasurer, Col. Grove-Hills, collected by his private efforts, with the approval of the Council, a Special Fund to meet the immediate financial difficulties of the Society. He aimed at securing £1800, and up to the present the total amount received from all sources (including dividends on the investments representing the fund) is £1913, 1*s.* 11*d.*, of which £1480, 2*s.* 10*d.* has been invested, and is now represented by £525 War Stock 5 per cent. 1929–47, £419, 17*s.* 11*d.* Conversion Loan 4½ per cent. 1940–44, and £695, 16*s.* Conversion Loan 3½ per cent. 1961. Part of the cash balance has been transferred from time to time to the General Fund to meet current expenditure, and in 1930 the whole of the remaining balance (£231, 1*s.* 3*d.*) has been thus transferred, as a contribution towards the expenses of decorating the Society's premises. In 1928 the Council resolved that the interest on the investments of the Special Fund should be regarded as part of the general income of the Society, and no longer funded.

	£	*s.*	*d.*		£	*s.*	*d.*
1930 Jan. 1. Cash Balance of Fund on Deposit ..	223	6	0	1930. Transfer to General Account	231	1	3
Donations in 1930	2	2	0				
Income Tax, 1926–27, refunded	5	13	3				
	£231	1	3		£231	1	3

Trust Funds.

The Lee and Janson Fund: In 1834 John Lee, Esq., LL.D., gave £100, and in 1876 T. C. Janson, Esq., bequeathed £200, the interest to be given to the widow or orphan of a deceased Fellow. These amounts now stand in £334, 10*s.* 9*d.* East Indian Railway 3-per-cent. Debenture Stock.

	£	*s.*	*d.*		£	*s.*	*d.*
1930 Jan. 1. Balance of Fund	16	15	6	1930. Grant from Fund ..	10	0	0
1930. Dividends, East Indian Railway ..	7	16	9	1930 Dec. 31. Balance of Fund	16	12	5
Income Tax, 1929 April–1930 April, refunded ..	2	0	2				
	£26	12	5		£26	12	5

The Turnor Fund and the Horrocks Memorial Fund: In 1853 the Rev. Charles Turnor, M.A., bequeathed a sum of £500, which now stands in £464, 18*s.* East Indian Railway 3-per-cent. Debenture Stock. In 1876 the Society received a sum of £38, 15*s.*, the unexpended balance of a fund collected for the purpose of erecting a memorial in Westminster Abbey to Jeremiah Horrocks: to this the Society

added the sum of £55, 15*s.*, and the whole now stands in £103, 6*s.* East Indian Railway 3-per-cent. Debenture Stock. The interest on these funds is to be used in the purchase of books for the Library.

	£	*s.*	*d.*		£	*s.*	*d.*
1930 Jan. 1. Balance of Fund	9	7	11	1930. Purchase of Books..	19	12	7
1930. Dividends, East Indian Railway ..	13	6	7	1930 Dec. 31. Balance of Fund	6	10	1
Income Tax, 1929 April–1930 April, refunded ..	3	8	2				
	£26	2	8		£26	2	8

The Harry Watson Memorial Fund: In 1920 Mrs. Watson presented to the Society, the sum of £300 as a memorial to her late husband, Lieut.-Col. Harry James Watson, F.R.A.S., the interest on this sum to be used for the purchase of books for the Library, such books to be indicated by a special book-plate. This gift now stands invested in £542, 18*s.* 2*d.* India 3½-per-cent. stock. In 1923 Mrs. Watson bequeathed a further sum of £958, 17*s.* 0*d.* to the Society, which now stands invested in £946, 6*s.* 11*d.* 5-per-cent. War Stock 1929–47. The Council resolved that these two sums should together constitute a Trust Fund, to be designated *The Harry Watson Memorial Fund*, to be used for the purchase and binding of books.

	£	*s.*	*d.*		£	*s.*	*d.*
1930 Jan. 1. Balance of Fund	10	12	5	1930. Purchase of Books..	9	12	0
1930. Dividends, India 3½ per cent.	19	0	0	Binding	29	12	6
Dividends, War Stock 5 per cent.	47	6	4	1930 Dec. 31. Balance of Fund	37	14	3
	£76	18	9		£76	18	9

The Hannah Jackson (née Gwilt) Fund: In 1861 Mrs. Hannah Jackson (*née* Gwilt) gave £300 Consols, which now stands in £309, 18*s.* 6*d.* East Indian Railway 3-per-cent. Debenture Stock; the interest to be given in medals or other awards in accordance with the terms of the Trust.

	£	*s.*	*d.*		£	*s.*	*d.*
1930 Jan. 1. Balance of Fund	26	2	1	1930 Dec. 31. Balance of Fund	35	4	7
1930. Dividends, East Indian Railway ..	7	5	4				
Income Tax, 1929 April–1930 April, refunded ..	1	17	2				
	£35	4	7		£35	4	7

The George Darwin Lectureship Fund: In 1926 June, the then President, Dr. J. H. Jeans, presented to the Society the sum of £1000 for the endowment of an annual lectureship, to be called *The George*

Darwin Lectureship, the lecture to be on some subject of interest to astronomers, preference being given, in electing a lecturer, to one normally resident outside the British Isles.

This sum has been invested in £988, 3*s.* 3*d.* 5-per-cent. War Stock 1929–47, and the income will be annually applied to the purposes of the Trust in accordance with the terms of the Deed of Gift.

	£	*s.*	*d.*		£	*s.*	*d.*
1930 Jan. 1. Balance of Fund	24	14	1	1930 May. Lecture Fee ..	50	0	0
1930. Dividends, War Stock 5 per cent.	49	8	2	1930 Dec. 31. Balance of Fund	24	2	3
	£74	2	3		£74	2	3

Celestial Photographs.

The following have been added to the list of Celestial Photographs reproduced by the Society for sale to the Fellows :—

R.A.S. Ref. No.

416. Pluto, Lowell Obs., 42-in. Refl., F.L. 220-in., March 2d. 4h. 56m.; 5d. 3h. 44m., Lampland.
417. Solar Corona, 1929 May 9, Takengon, 6¾-in. lens, F.L. 15-ft., Exp. 70 sec., Miller.
418. Moon, Mare Nectaris to Haemus Mts., 24-in. Refl., Exp. 1½ sec., 1928 May 25, Tomkins.
419. Moon, Haemus Mts. to Mare Imbrium, 24-in. Refl., Exp. 3¼ sec., 1929 Nov. 21, Tomkins.
420. Moon, Mare Nectaris to Plato, 24-in. Refl., Exp. 1¾ sec., 1929 Nov. 17, Tomkins.

Publications of the Society.

During the past year the Society has published *Monthly Notices*, vol. xc.; *Geophysical Supplements*, vol. ii., Nos. 5, 6; and *Memoirs*, vol. lxv., part 1.

Memoirs, Vol. lxv., pt. 1. J. E. de Vos van Steenwijk, A Catalogue of the Mean Places and Proper Motions of 1732 Southern Stars, mostly between − 30° and the South Pole, for the Equinox of 1900.

Obituary.

The Council regret that they have to record the loss by death of the following Fellows and Associate during the past year :—

Fellows :—Harold John Adams.
John Turnbull Bird.
Richard Henry Bulkeley.
Charles Eddie.
J. William Gifford.
George Thorn Gwilliam.
Edward Ball Knobel.
Albert Taylor.
Francis Anthony Tondorf.*
Herbert Hall Turner.
Richard Wilding.
William Wilson.
Hugh Montague Wood.
Alfred Ernest Young.
Associate :—Johann Georg Hagen.

Harold John Adams, who was born in London on 1858 January 20, was educated at Margate, at University College School, and at St. John's College, Cambridge, where he was a Wrangler in the Mathematical Tripos in 1879. In 1881 he entered H.M. Patent Office, where he served till 1922, retiring with the rank of Senior Examiner. He married in 1885 Georgina Pye, daughter of James Pye of Cobham, Kent, and had three daughters and one son who died of wounds in the Great War on 1917 February 27, aged 26 years. He always took a great interest, though not an active part, in the Society's meetings, and the recent developments in astronomy exercised a great fascination over him. He died at Beckenham, Kent, on 1930 April 22, and is survived by his widow and three daughters.

He was elected a Fellow on 1893 February 10.

The Rev. John Turnbull Bird was born at Fishwick, Berwickshire, in 1862. He was educated at Edinburgh University, taking his M.A. degree there at the early age of eighteen. After completing the theological course he was licensed in 1884 by the Presbytery of Edinburgh. For two years he conducted the mission station at Aberfeldy, and for three years he was assistant in St. Stephen's, Edinburgh. In 1891 he was ordained an army chaplain, and in this capacity served in the Boer War and the European War, being twice mentioned in despatches and receiving the high honour of C.M.G. Retiring in 1921, he devoted part of his leisure to the preparation of a book, *Christianity and Science*, which was published in 1927. His chief interest in astronomy centred in the Variable Star Section of the British Astronomical Association, and he worked for several years in collaboration

* Died 1929; death not reported till 1930.

with the late Col. Markwick. To enable him to prosecute this work he was presented with a telescope, which he later handed over to the B.A.A. This telescope is now in the care of the West of Scotland Branch. Mr. Bird was a man of high character, of warm affection and engaging modesty of manner. He died suddenly on 1930 July 21 while on holiday in Northumberland. He leaves a widow and one daughter.

He was elected a Fellow on 1912 June 14.

Richard Henry Bulkeley was born on 1862 April 30 at Young, New South Wales. He was in business first at Wallerawang, N.S.W., and later at Sydney. He was President of the Blaxland Shire Council, and had earlier been a churchwarden of St. John's Church of England at Wallerawang. He was from an early age interested in astronomy and was the possessor of a six-inch reflecting telescope. He was a member of the parties that observed the total solar eclipses of 1911 at Vavau in the Pacific and of 1922 in Queensland. He became in 1895 a member of the British Astronomical Association, in which he held the office of Auditor of the New South Wales Branch for many years, and at the time of his death was one of its Vice-Presidents. He married Mary Eleanor Brown, his family consisting of one son and three daughters. His son, after being awarded the Military Cross in the European War, was killed in action on 1916 August 17, aged twenty-six years. Mr. Bulkeley was a member of the Royal Australian Historical Society. He died at Mosman Bay, near Sydney, on 1930 May 25.

He was elected a Fellow on 1914 February 13.

Captain Charles Eddie was born at Bilbo Hall, near Elgin, on 1854 January 18. When sixteen years old he went to sea as an apprentice in a ship of the City Line (of Glasgow), and sailed all over the world in windjammers. Leaving sail, he secured his master's certificates, and at the age of twenty-seven he was in command of a first-class passenger steamer. He spent the greater part of 1886 trooping in connection with the Burmese War. For a number of years he was in command in the Persian Gulf, Coast of India, China, and Malay Archipelago. He was an accomplished horseman and an expert with the sabre and lance, and he had the distinction of riding at the head of the troop of Sowars who form the bodyguard of the Sultan of Perak. While in Penang he edited the marine section of the *States Maritime Journal*. Settling in 1908 in Vancouver, he founded the Naval Volunteer movement there, and when the Navy League bought H.M.S. *Egeria* for the purpose of training boys for a sea-faring career, he undertook their training without any recompense. For seventeen years he was Supervising Examiner of Masters and Mates, Western Division, for the Department of Marine and Fisheries of the Dominion of Canada, and earned high tributes from the Dominion Commissioners. Retiring from this position in 1924, he opened a School of Navigation and also a small business dealing in nautical and scientific instruments. He was a very well-known and respected

figure in Canadian shipping circles. He was a Fellow of the Royal Geographical Society.

He died of pneumonia on 1930 March 12 at St. Paul's Hospital, Vancouver.

He was elected a Fellow on 1911 January 13.

J. William Gifford was born at Chard, Somerset, on 1856 February 29. He was a lace manufacturer, and at the time of his death, at Chard on 1930 October 27, was chairman of Messrs. Gifford, Fox & Co., of Chard and Nottingham. He married in 1883 Emma, daughter of Ernest Rossiter, solicitor, of Taunton, and had four daughters and one son, who all survive him.

He had a deep interest in, and was very well informed upon Astronomy, but his principal scientific work was in the field of applied optics. The improvement of telescopic objectives and eyepieces was a matter of his special concern. He computed, and caused to be made, several lenses, and had in his grounds at Oaklands, Chard, a small observatory with a very remarkable telescope of five inches aperture with a quartz-fluorite objective, made from part of a stock of material he secured many years ago in Switzerland. A book written by him on *Lens Computing by Trigonometrical Trace* was published in 1927 by Messrs. Macmillan. Papers by him have been published by this Society—"An Improved Telescopic Triple Object-Glass," *M.N.*, **69**, 118 (1908), and "Telescopic Triple Object-Glass of High Relative Aperture," *M.N.*, **84**, 175 (1924),—by the Optical Society, and by the Royal Society, and he has published trigonometrical tables computed by himself and his wife.

The precise measurement of refractive indices formed an important part of his work, especially that done in collaboration with Professor T. M. Lowry, and he had in his private laboratory a spectrometer of his own design specially adapted for the improved methods he devised. He has bequeathed this instrument to the Imperial College of Science and Technology.

In 1881 Gifford became a member of the Volunteers, and at his death was Hon. Colonel of the 5th Battalion of the Somerset Light Infantry, with which he was connected all his life. He was not allowed, on medical grounds, to serve in France at the outbreak of war in 1914, but he was sent there later as an expert in optical design to report upon giant periscopes which the Germans had just installed, and which our Government wished to put up also. He reported against them as serving only to draw fire, and shortly after the Germans removed their instruments, thus proving the value of his advice.

In these days, when lengthy and laborious determinations of physical quantities are not very much in fashion, except perhaps the measurement of wave-lengths of light, his work in spectroscopy is deserving of rather more recognition than it has generally received.

Colonel Gifford was a man of quiet ability and considerable charm of manner. He was elected a Fellow on 1909 January 8.

J. A. C.

Edward Ball Knobel was born in Baker Street, London, on 1841 October 21. He was the second son of William Edward Knobel, a solicitor in Lincolns Inn Fields. His mother's family were closely connected with the Exchequer. She was the eldest daughter of William Henry Roberts, Deputy-Clerk of the Pells, who was the son of Edward Roberts, Clerk of the Pells in succession to Addington and Barré.

Mr. Knobel received his early education at La Capelle in France, and subsequently at the Stockwell Grammar School. On leaving school he read law for a couple of years, but having a strong enthusiasm for geology he, in 1861, entered the Government School of Mines in Jermyn Street with the intention of working for the Geological Survey. The course of study was for three years, but he decided to take the subjects of the first two years at once; but though in 1862 he passed all his examinations with credit (for which he was complimented by Sir Roderick Murchison) he gave up this branch of study, and was recommended by Professor A. W. Hofmann to Messrs. Bass & Co. at Burton-on-Trent to fill a vacancy in their brewery staff as analytical chemist. Here he remained for thirteen years, and became a Manager and Head Brewer. Subsequently he was appointed Manager at Messrs. Courtauld & Co.'s silk factory at Bocking, where he remained for many years; but the continued ill-health of his wife in the country compelled him to relinquish this position and remove to London, where he was appointed Managing Director of the Ilford Photographic Company.

His interest in Astronomy date from childhood, when at eight years of age his imagination was roused by some elementary scientific books; and being taken soon after on a geological excursion, the investigation of the fossils he then found influenced the whole of his subsequent life and led to his devoting himself to a scientific career. In the early 'sixties he acquired a 3-inch telescope, and in 1872 he purchased an 8½-inch reflector by Browning. With these instruments he made many observations and drawings of Sun, Moon, Planets, Comets, and Nebulæ. He devoted himself particularly to photometry, and invented an astrometer with which he made many observations of the brightness of stars by the method of limiting apertures, and published the results in the *Monthly Notices*. He also made a large number of measures of double stars with a double-image micrometer. In 1875 he prepared a Reference Catalogue to certain astronomical researches (*M.N.*, vol. xxxvi.) which involved the laborious work of going through every volume of the *Transactions* of Academies in the library of the Royal Society. It is unfortunate that time did not permit of making this catalogue in more detail. In the course of this work he prepared a Memoir on the Chronology of Star Catalogues (*Mem. R.A.S.*, vol. xliii.). This investigation led him to the study of Oriental astronomy and to acquire some knowledge of Arabic and Persian. In 1879 he published a translation from a Persian MS. of Ulugh Beg's catalogue of stars. At this time he determined to collate Greek, Latin, and Arabic manuscripts of Ptolemy's *Almagest* with the object of obtaining a more correct edition of Ptolemy's catalogue of stars than the printed editions furnished. Some years

later he learned that Prof. C. H. F. Peters was occupying himself with the same subject, and accordingly proposed to join forces and to place all the materials he had collected at Professor Peters's disposal. On the latter's death in 1890 all his notes and manuscripts were sent to Knobel to prepare for publication. No means of publication seemed possible in this country, but an appeal to the Carnegie Institution of Washington resulted in the whole work being published by them in 1915. Knobel then took up the collation of some thirty Persian manuscripts of the star catalogue of Ulugh Beg, which was published by the Carnegie Institution in 1917.

Knobel's last instrumental work was a short series of observations of Mars at the Opposition of 1884, when the north pole of the planet was turned to the Earth (*Mem. R.A.S.*, vol. xlviii.). This contribution is typical of Knobel's gift of seeing something that should be done and doing it. Though excellent drawings of this planet had been made by others, these were mainly of its southern hemisphere, because at times when the north pole is in view Mars is near aphelion, and the small apparent diameter of the planet had led to its neglect. This, however, did not deter Knobel, and though he was not favoured with specially fine weather he produced with Mr. Wesley's help a series of drawings that form a valuable item in the records of the planet's surface. Though from this time forward his actual personal astronomical work was of a literary nature, as above described, his experience as an observer, and the knowledge he had necessarily gained in reduction of observations for the editions of ancient catalogues, made him a vigilant critic of many branches of astronomy, and there were few subjects brought before the meetings on which he was not able to offer an opinion. In 1910 he accepted the invitation to become President of the British Astronomical Association, though it may be said in passing that the foundation of that body in the year 1891 had not met with his complete approval, for he feared lest it might have an adverse effect on our Society, whose welfare he had so much at heart. Later, however, the organisation had his warm encouragement, and an address on " Numerals in Ancient Manuscripts " which he delivered before the Association at a meeting in 1908 May, and which embodied much knowledge that he had gained in his study of the *Almagest*, may be read in the *Journal* of the Association of that date. In the first of his Presidential addresses he spoke of the prominent features of the astronomy of the day, and for his second he took the subject of " Stellar Photometry," on which he was so competent to speak, giving concise but complete descriptions of various methods (*B.A.A. Journal*, vol. xxiii.). The speeches of thanks on this occasion were of more than *pro forma* sincerity. They recounted how the Association during his term of office had become an incorporated company, necessitating a great deal of work of which Mr. Knobel had taken the lion's share, and in which his business knowledge and the care with which he entered into every detail were invaluable. A remark made on the occasion by one who knew him well may be mentioned—that it was a pleasure to consult Mr. Knobel on any

subject, because he could always enforce his advice by reference to old precedents and memories of astronomers who might not have been known to many of his contemporaries. The qualities thus implied were among those that made him valuable to the Society. He was always ready to help tactfully, but firmly and efficiently. To go back to an early period in his career for an instance, reference may be made to what was known as the Sadler-Smyth scandal, which occurred in 1879; Mr. Knobel volunteered to enquire into this, and brought it to a satisfactory conclusion by a paper of twenty-five pages in the *Monthly Notices* for 1880 June.

It is a little difficult to give to those who did not know him an adequate idea of the many-sidedness of Dr. Knobel's interests. He was a Fellow of the Geological Society for twenty-five years. He received the Honorary Freedom of the Spectacle Makers Company in 1899. Literature and art appealed to him almost as much as science. He was an enthusiastic musician and played the violin. For twenty-three years he played in the orchestra at the Festival performances at the Crystal Palace. He played violin solos at numerous concerts and was on the Council of the Queen's Hall Sunday Concert Society. He was often to be seen at Lord's Cricket Ground. His services to Astronomy, particularly his editions of part of Ptolemy's *Almagest* dealing with Astronomy, and of the catalogue of Ulugh Beg, were recognised in 1927 by the award of an Honorary D.Sc. by the University of Oxford. On the occasion of the conferring of the degree, the Public Orator said: That from his earliest years Dr. Knobel had devoted himself to astronomy, and was distinguished as a writer *inter illos qui artis omnium candidissimæ historiam persequuntur.* He was *siderum codicumque scrutator*, an expert in Oriental languages as well as in astronomy, both ancient and modern, under whose guidance we could follow the courses of the stars *si non ab Aenea et Palinuro, at certe ab felicissima illa Antoninorum aetate.* He had edited that part of Ptolemy's *Almagest* which contains the catalogue of the stars, with such care *ut auctoris eruditi non verba tantum, teneret, sed etiam numeros.* By his skill as a palæographer he had in many places restored the numbers corrupted in transmission, and had reduced to order Ptolemy's lists of the stars. He had also edited the catalogue of the stars made five hundred years ago on the basis of Ptolemy's work by Ulugh Beg, *invicti ducis Tamerlani nepos.* If that King, who was described as *doctus et in mathematicis perfectus*, were alive to-day, he would be thought worthy of all honours, and Oxford therefore welcomed his interpreter, *senem indefessum, astronomiæ antistitem.*

Dr. Knobel was elected a Fellow of the Society on 1873 March 14, and served on the Council continuously from 1876 to 1922, when he retired on the death of his wife, but allowed himself to be re-elected in 1923. He served the office of Secretary for ten years, was President in 1892 and 1900, and was Treasurer for many years. He was constantly on the House Committee, the Photographic Committee, and the Library Committee. His wide knowledge and the ease with which he read foreign languages made him a useful guide in the choice of books. He

was always ready to take trouble about cataloguing and binding and the rearrangements which from time to time are required in a library. On the Council he was very conservative in anything concerning the conduct of the Society, *e.g.* he opposed the alteration of the hour of meeting, but when this change was once made accepted it with the utmost loyalty. On the other hand, he took an active part in the movement to admit women to the Fellowship of the Society, though he had been an early opponent of this measure. His colleagues on the Council and many friends in the Society will always remember him with affection.

Dr. Knobel married Margaret, daughter of Henry Whitehead, in 1869. Her death occurred in 1922, after fifty-two years of the happiest wedded life. He leaves a family of two sons and two daughters. He was blessed with good health till the last few months of his life. He died on 1930 July 25, full of years of happy and useful activity.

F. W. D.

The Rev. Francis Anthony Tondorf, S.J., was born at Boston, Mass., the son of Joseph and Louise Musler Tondorf. Deciding in early manhood to join the Society of Jesus, he studied at Woodstock College, from which he received the degree of A.B. in 1895. For the next two years he acted as Professor of Physics at Loyola, and from 1897 to 1899 he continued his studies at Johns Hopkins University. He was a man of wide scientific pursuits and accomplishments, as his further academical activities show. In 1905 he became Assistant Observer at Georgetown Observatory, collaborating with the late Father Hagen, who subsequently became the Director of the Vatican Observatory. In 1913 Father Tondorf was elected Professor of Physics at Georgetown. At the time of his death he was Professor of Geology at the College, and also taught in the Medical School as head of the department of Physiology. Father Tondorf's best work, however, was done in Seismology. He is largely responsible for the development of the seismological station at Georgetown, which is one of the best equipped in the world.

He received the degree of Ph.D. from Georgetown in 1914. He belonged to many scientific societies, including the Meteorological Society, the American Seismological Society, the Geophysics Union, the Washington Academy.

In view of his various duties and interests, he had little time for rest. In addition to his teaching duties, he would continue his own seismological work until midnight and be content with only four hours of repose. He died on 1929 November 29, and is survived by one sister, Mrs. Mary Galvin of Chestnut Hill, near Boston, Mass.

He was elected a Fellow on 1927 February 11.

Professor H. H. Turner, who died at Stockholm 1930 August 20, four days after an attack of cerebral hæmorrhage while occupying the chair at a meeting of the Seismological Section of the International Union of Geodesy and Geophysics, was elected a Fellow of the Society

in 1885 January. He was elected to the Council in 1887, acted as Secretary from 1892 to 1899, filled the office of President from 1903 to 1905, and had discharged the duties of Foreign Secretary since 1919. As an outstanding figure in the affairs of the Society over a continuous period of more than forty years he has made as great a mark on its history as any other Fellow of his generation. He was fitly joint editor and contributor to the centenary *History* of the Society.

Herbert Hall Turner was born at Leeds, 1861 August 13. His father, John Turner, met with a railway accident and received injuries which prevented him from pursuing his profession as an artist. As a result the family fortunes were severely straitened, and Herbert, the eldest child, was thrown very much on his own resources, by scholarships and later by private coaching, to provide the means for his own education from an early age. In this way he went from Leeds Modern School to Clifton College in 1874 and was in Dakyns's House till 1879. He has been described as lithe and active in those days and something of an athlete. In the school cross-country run of 1879 he came in tenth (reckoned a good performance), and at football he won his cap as a forward without actually being in the school fifteen. A photograph exists of a football group at Clifton, in which Turner and his contemporary Haig (afterwards Earl Haig) are both included. The following note has been kindly supplied by Canon J. M. Wilson, who became Headmaster of Clifton a term before Turner's schooldays ended :

" I strongly advise everyone who wishes to realise how H. H. Turner was educated at school to read *Clifton College School Days, 1879–1885* (pp. 19–21), by O. F. Christie. He will see there a complete list of the members of the Sixth Form in the summer term of 1879, which was at once his last term at school and my first. I think when he reads what has become of all those boys he will sympathise with me in saying, as I did in the *Life of Bishop Percival*, whom I succeeded, that ' I cannot be wrong in thinking that the Sixth Form, which in fear and trembling I took in May 1879, was a remarkable one.'

" Anyone who reads that list * will feel that Turner's schoolfellows, with whom he must have consorted all the five years of his life, from the lowest form at thirteen to the upper bench of the Sixth at eighteen, must have been a potent force in his school life, and he will learn what must have been the spirit of the School.

" Of incidents in his schooldays, after the lapse of fifty-one years, I have small recollection. But in reading Plato, *Republic*, Book I., with the Sixth, he caught my special attention as interested, along with others, in the matter as well as in the language. He seemed also so pleasant that I invited him to go abroad with me for a short trip in the holidays, when I formed a lasting friendship with him. I had no share in teaching him mathematics at school : Watson and Steggall were his excellent teachers in that subject ; and in physics and chemistry Macgregor and Tilden, both subsequently Fellows of the Royal Society.

" I recollect him quite clearly at Clifton ; and for some years after

* Among other interesting names it includes those of Henry Newbolt, Thomas Heath, Christopher Cookson, St. John Gray.

he was Professor at Oxford he was good enough to 'jackal' for me in astronomy, telling me of anything important. I had formerly been on the Council, but gave up membership when I came to Clifton. His diligence and versatility impressed me greatly."

Evidently Turner enjoyed the advantages of a classical education. But two incidents reveal his natural bent. In the school debating society he successfully opposed the resolution "That the study of the classics is necessary for the development of the intellect." He also became treasurer of the school scientific society. His devotion to Clifton was lifelong, and was marked only recently by the gift of the carved oak seats which adorn the new science library.

From Clifton Turner went to Trinity College, Cambridge, with a Foundation Scholarship in 1879 October. The set which he joined with a high reputation as a mathematician included such men as Sir Walter Raleigh, Mr. A. Hamilton Smith, Sir Harry Stephen and his brother J. K., and Sir Harry Wilson. He has been described as being in those days alert, vigorous, simple in his tastes, and rather philistine in relation to the movements then in fashion; and by another contemporary as the most kindly and cheerful person, entirely free from any pedantry. He was devoted to whist, which kept him from bed till any hour of the morning, and an excellent player. He won the Sheepshanks Exhibition for Astronomy (founded, it may be noted, by another native of Leeds) after a short period of preparation. But Turner evinced little sympathy with star-gazing for its own sake, and does not seem to have given much attention to the subject of astronomy before his professional appointment at Greenwich. It is unlikely that he had much time for it. Force of circumstances compelled him to be something of a "pot-hunter," if the word may be used in an entirely creditable sense. He won a number of prizes not only at Cambridge but also at London University, thereby supplementing his scanty means. In this object Turner may have owed something to his intimacy with R. C. Rowe, a Fellow of Trinity, at that time dividing his time between Cambridge and London, where he was Professor of Mathematics at University College. Rowe was also an excellent musician and stimulated Turner's natural taste for good music; he may have been responsible for introducing Turner to a musical set at Cambridge which included Sir C. V. Stanford.

In all ways Turner's life at Cambridge must have been a particularly happy and fortunate one. He enjoyed a congenial circle of friends, destined to earn distinction in later life. Success came to him as a student and smoothed his path. Recreation, even the opportunity for the outlet of high spirits, was not wanting. In the Tripos of 1882 (Parts I. and II.) he was second wrangler, and the following year he was placed in the first division of Part III. and awarded the second Smith's prize. Election to a Fellowship at Trinity followed in due course. Dr. Routh had been his private tutor. It may not have been the most brilliant period in Cambridge mathematics, and Turner had no occasion to develop his mathematical knowledge afterwards in his professional capacity. But if his armoury was limited, his weapons

were finely polished. He had true mathematical taste, especially as a geometer, his own work was always neat and he had ready appreciation for elegance in the work of others. His career at Cambridge was followed at no long interval by his appointment to the Royal Observatory at Greenwich.

When Turner went to Greenwich as Chief Assistant in 1884 it was a propitious moment for a young man with energy and ambition. Airy's reign of tidy routine had come to an end three years before. The Royal Observatory was on the eve of that great expansion which marked its history in the next twenty years. After the mid-Victorian period of quiescence a new life was beginning to stir in the veins of astronomy, the early signs of that development which preluded the efflorescence of the early years of the present century. With the licence of the skilled popular lecturer Turner was wont to date the photographic era in astronomy from the Cape photographs of the comet of 1882. For this curtailment of history he had at least two good excuses. The event did signalise the arrival of the dry plate; it also heralded his own professional career, which was to be so deeply influenced by the introduction of new methods and new ideas.

From the start Turner established his position and was recognised as a "live wire" both within the Observatory and without. To Christie he proved a loyal and efficient lieutenant; the Astronomer Royal had only one Chief Assistant in those days. To the staff, and especially the junior staff, accustomed to the Olympian aloofness of Airy, here was a human being utterly free from convention or self-consciousness, ready to help everyone, to join in their sports, and even to their failings not a little kind. In the outer circle of people interested more or less actively in astronomy, with their natural propensity for new developments, Turner was welcomed as a kindred spirit combining the sympathies of the amateur with the knowledge and, as time went on, the experience of the professional. And, as time went on, this circle expanded till it embraced the whole earth. If for a moment reference be allowed to the bitterness which the War undoubtedly brought to him, let it be recalled that few had done more than he, within his own limited range, to promote harmony and goodwill. The measure of his disappointment can be imagined.

In the nine or ten years spent at Greenwich, Turner found varied opportunities for gaining experience in practical astronomy. It is many years since the "R—D" discordance and anomalies of personal equation could arouse much interest, but these were subjects to which he gave repeated attention without any striking success. Of the part he played in the scheme which came to be known as the Astrographic Chart from 1887 onwards mention will be made later. Here it is convenient to refer to the many occasions which took him away from Greenwich, for those journeys on astronomical or other scientific business which formed a remarkable feature of Turner's life and culminated in his death were begun at a very early point in his career. The Paris-Greenwich longitude determination of 1888 was his first experience of this kind of work. It left outstanding uncertainty

and was repeated in 1892. In the latter year the Montreal-Greenwich determination took Turner further afield ; the result in this instance has required no revision. But these were not the first of his scientific journeys. As early as 1886 Turner went to the West Indies (Grenada) on his first eclipse expedition, when he made visual observations of the spectrum of the inner corona. His second expedition, to Russia, in the following year was less fortunate owing to cloud.

To pursue the subject of eclipse expeditions beyond the years at Greenwich, Turner went to Japan in 1896 and was again defeated by cloud ; to India (Sahdol) in 1898, to Algiers in 1900, and lastly * to Egypt (Aswan) in 1905. Thereafter he remained a member of the Joint Permanent Eclipse Committee, and his experience and encouragement were behind all the later British enterprises in this field. He began, as stated, with a modest programme of visual observations. Later, photography came to his aid and he secured records of the form of the corona. By photometric methods due to Abney he investigated the law of coronal density. These researches may have a greater value when the structure of the corona itself comes to be better understood. But an even greater service than any positive results from these expeditions may, perhaps, be found in Turner's consistent advocacy of the advantages of the cœlostat. This beautiful instrument, now firmly established as an essential element in the tower telescope, was not so familiar thirty years ago. He was not the inventor of it, but he was perhaps chiefly responsible for its subsequent application. Lippmann's first description of the cœlostat seems to have appeared in 1895 ; thanks to Turner's promptness and energy, three instruments of this type were available for the eclipse of 1896.

The Observatory magazine, which emanates from Greenwich Observatory, was founded by Christie in 1878. It was edited by Turner, with various collaborators, between 1888 and 1897. The Oxford Notebook, with its carefully preserved fiction of anonymity, was started in 1894, emerging through similar paragraphs over the initials H. H. T. from the form of ordinary editorial notes. This genial record of passing events, appearing in more than four hundred monthly parts, has been read with delight by astronomers the world over. It is so familiar to all that a mere mention of this feature of the magazine will recall the universal debt to the writer, and bring to mind a common sense of loss.

When J. C. Adams died in 1892 Turner had earned such a position at Greenwich that little surprise would have been felt if he had been appointed in succession to the Lowndean Chair at Cambridge. Though this did not happen, it is a little difficult to resist the temptation to speculate on the way in which the history of British astronomy might have been deflected by a different choice. For in the following year the death of Pritchard left the Savilian Professorship at Oxford vacant, and Turner became his natural and obvious successor. In this post he was to remain for the rest of his life ; his attachment to Cambridge was so deep that this destiny was probably not altogether to his liking and may have left regrets. But the fates had so decided.

* But for Southport in 1927.

Apart from the question of personal preference (and this is a matter of conjecture), Turner's appointment at Oxford was certainly fortunate at that juncture. Pritchard, who is entitled to some place among the pioneers of astronomical photography, had embraced the scheme of the "Carte du Ciel" with enthusiasm. So keen was he on undertaking the work, and so far from realising its implications, that he was anxious to embark on it with the small reflector then in use at Oxford. When the Conference adopted the refractor designed and constructed by the Brothers Henry at Paris as the standard instrument Pritchard was disappointed. The difficulty was overcome by the generosity of Warren de la Rue, who provided the University Observatory at Oxford with a telescope of the accepted pattern. Thus Turner came, early in 1894, to an observatory committed, like Greenwich in this country and sixteen other observatories abroad, to a share in the Astrographic Chart and Catalogue. For carrying out the task he had the right kind of telescope, never altogether efficiently mounted, a single assistant (Mr. F. A. Bellamy), and his own energy, partly required for academic duties, which were never neglected. On the financial side he had a meagre annual grant calculated for an observatory of this modest establishment, with no ready means for its expansion.

In these circumstances, and with due regard to the proper function of an unendowed university observatory, excuses might have been found for repudiating the whole undertaking, especially at that early and largely experimental stage of the work. And one part, the production of a chart based on long-exposure plates, was never seriously contemplated at Oxford. For the other part, the taking of the necessary catalogue plates could be regarded as feasible. But this was only one in four distinct stages, the others being the measurement of some 400,000 star images, the reductions required to make it possible to infer the corresponding star positions and magnitudes, and finally publication.

Turner, however, was never dismayed by the magnitude of any enterprise, though at the same time, aware of the infirmity of human nature and the unforeseen hazards to which all schemes are liable, none was more insistent on the need for practical limitations. Moreover, he was specially equipped to cope with the position both by natural gifts and by experience. He had a positive genius for exploiting unskilled or semi-skilled labour in the service of science. At Greenwich he had been in the closest touch with the new problems from their inception. On the instrumental side he had devised a new measuring instrument which, by the substitution of an eyepiece scale for the micrometer screw, had at a certain sacrifice of precision made it possible to secure measures in the mass with extraordinary rapidity. The mere multiplication of cheap machines in itself proved very convenient, while the precision offered by other types could only be secured at the cost of far greater labour and a degree of skill and care difficult to sustain on the highest level through a work of this magnitude. From an early stage Turner had the plates measured in two opposite orientations (involving something like a million measures), a safeguard against certain systematic errors as well as gross mistakes. An annual grant

from the Royal Society enabled him to enlist a succession of boys on leaving school. They rapidly became proficient in the use of the measuring machine and thus provided for this side of the work. In the circumstances it could hardly have been done at all in any other way. An attempt at greater refinement would have been fatal.

Side by side with the work of measuring, the work of reduction was carried on. Here the methods introduced by Turner are of outstanding importance and liable to be less than fully appreciated, partly because in the end and in all essentials they have become a common inheritance and partly because the circumstances in which they were evolved are likely to be forgotten. Half a century ago the mode of astronomical thought was in terms of the sphere, with its handmaid spherical trigonometry. With the advent of the flat plate into common use, the same conservative mode persisted. To Turner more than to anybody else is due the introduction of a different point of view. The celestial sphere is, after all, only one form of projection, though for many purposes doubtless the most convenient. But the photographic plate is itself a form of projection, equally for its own purpose the most suitable. Pushed to the limit the plate recedes to infinity, but this defect can be evaded. Thus Turner was led to suggest the representation of an entire sphere on the faces of a cube, an idea put to useful account by Mr. Hinks. But short of this, the positions of points on the sphere determine the rectangular co-ordinates of corresponding points on an ideal plate with assigned centre and orientation, free from the effects of refraction, aberration, etc. These are Turner's *standard co-ordinates*, which also allow of the inverse transformation to the sphere. There remains the question of the relations subsisting between the standard co-ordinates and the co-ordinates actually measured on a photographic plate. To some extent these are simple and obvious, as in the case of the orientation of the axes of reference, or of the scale. In other respects they are less so, as in the case of refraction, where in practice the treatment must depend partly on the area covered by the plate and partly on the degree of precision in view. In a series of characteristic papers marked by a peculiar elegance Turner discussed the various sources of error. The main outcome was that, for the purpose of work like his own at Oxford, the relations between standard and measured co-ordinates are linear within the needful limits of accuracy. This conclusion, which was not allowed to pass without controversy, greatly simplified the reduction of the astrographic plates at Oxford. The youthful staff engaged in the work of measuring was quickly trained to calculate the standard co-ordinates of the reference stars from various A.G. Catalogues, using special tables for the purpose, and plate constants were then deduced by a very simple form.

Thus at small cost the work of preparing the Catalogue went rapidly forward, and in about ten years from its real beginning in 1894 the end was in sight. This was in advance of all the other observatories similarly engaged, but the precise date is immaterial because the final stage of publication had still to be provided for. In the meantime Turner himself had embarked on a number of other researches and allowed his

permanent staff a similar latitude. When the arrangement was finally made by which the cost of publication was shared between H.M. Government and Oxford University a certain delay had occurred and the staff of young computers had been depleted. The date of completion of the Catalogue in a published form (1911) was creditable enough, but it would have been earlier still had it not been for causes over which Turner himself had no control. What it is possible to accomplish on Turner's lines with a staff entirely devoted to the single purpose and unhampered by financial hindrances is perhaps better shown by the corresponding work at Hyderabad on the zones between − 16° and − 24°. This was directed by Mr. Pocock, who had been trained at Oxford and unfortunately died (1918) at an early stage of the work; it was begun in 1914 and finished in 1930. But the results for the four (out of seven) zones originally contemplated were published by 1921.

The section of the Astrographic Catalogue assigned to Hyderabad in substitution for a defaulting observatory may be regarded as a sequel to the Oxford section, since it was inspired and supported by Turner. In the case of the Vatican zones (+ 55° to + 65°) the help given from Oxford took a more direct and concrete form. The plates for this section were taken at the Vatican Observatory and measured by nuns. The measures were then forwarded to Oxford, where the work of reduction was carried out under Turner's direction and the publication of the whole was supervised. To commemorate this service Turner and his assistants received special medals from H.H. The Pope. Nor does the story of Oxford's connection under Turner with the Astrographic Catalogue stop at this point. After the war, Potsdam found itself unable, owing to financial pressure, to complete the zone (+ 31° to + 40°) it had undertaken. At the I.A.U. meeting at Leiden in 1928 Turner made proposals for completing this zone, and the work had already been begun at Oxford before his death. It is greatly to be hoped that this gallant undertaking will be fully carried out. While other observatories have fallen by the way, Turner persisted with unflinching zeal; the seal will be set on his greatest achievement if his name is connected with nearly a quarter of the entire scheme. In some respects his share is even greater. He was in the movement from its inception and played an influential part from the beginning. He survived successive leaders as they fell until, as President of the Astrographic Commission of the International Astronomical Union, he became for the last ten years the acknowledged leader himself. Throughout he has lent encouragement to the willing, a helping hand to the weak, and fearless criticism where it seemed to be deserved. He will fail of his just reward if the last remnants of this great undertaking be left unfinished.

One reward of a peculiar kind came to Turner. By his discovery of Nova Geminorum (1903) his name will remain in the short list of those who have detected extra-nebular objects of this class. There must always be an element of luck in such an event, but in this case it may be regarded as a just reward for the close personal control he maintained over every detail of the work under his direction.

Turner himself regarded the Astrographic Catalogue as a great document prepared for the use of posterity. But this did not deter him from making such use of it as the limited difference of epoch between the plates allowed, and several lists of stars with considerable proper motions have been published. The range of his discussions is very wide. He was well aware of the great weakness to which the Catalogue is subject in the matter of the magnitudes, and made great efforts to overcome it. The simplicity of his methods is well illustrated by the use which he made of counts of stars in different regions of the plate. But the astrographic telescope is essentially a charting instrument, less suitable for the purpose of statistical studies, and Turner can hardly be said to have surmounted this defect. He himself pointed out consistently the advantages presented by the doublet with its larger and more uniform field.

Some tribute has already been paid to Turner's geometrical insight into the nature of the photographic plate as a projective form. This will be recognised as his outstanding merit on the mathematical side. For the older method of spherical trigonometry he substituted the elements of solid geometry with its apparatus of simple determinants, so well adapted to dealing practically with the recurring problems of transformation. As an example may be quoted the paper "Some Suggestions for the Explicit Use of Direction Cosines or Rectangular Co-ordinates in Astronomical Computations" (*M.N.*, **60,** 201, 1900). This reference will also serve to recall Turner's helpful association with the late Mr. S. A. Saunder, which contributed materially to the latter's important work on lunar topography. By the same chain of events Turner was drawn into the Committee on Lunar Nomenclature, which occupied much of his time for a period before and, still more, after Saunder's death in 1913.

After the Astrographic Catalogue, the main current of Turner's activity was turned to variable stars, with allied researches in many directions; to suggest the connecting link some word like *periodography* seems required. In his capacity as Secretary of the Society he first edited volume **52** (1899) of the *Memoirs*, which contains the observations of George Knott. This led to an appeal to perform a similar service for the observations made at Sir Cuthbert Peek's observatory at Rousdon, and again Turner responded to the appeal; volume **55** (1904) of the *Memoirs* is the outcome. Once more a like request was made when the older observations made by Joseph Baxendell and by Pogson were placed in his hands. Those by Pogson were edited by Mr. C. L. Brook (*Mem. R.A.S.*, **58,** 1908); the remainder were edited by Turner with the assistance of Miss M. A. Blagg, and published in instalments (*M.N.*, 1907–18). The whole series illustrates Turner's readiness to take unstinted pains in order that the work of others might be made to yield its utmost value.

While in other men inertia is the cause of inactivity, so the momentum produced by all this work of edition and discussion led Turner further than he himself was perhaps fully aware. When Professor Karl Pearson introduced new methods into the treatment of statistics, Turner

was among the first to recognise their value, and became an eager exponent. He was always ready to help anthropologists and others at Oxford who needed his assistance in this part of their work. With the methods of harmonic analysis he had been familiar from the beginning of his career, and Schuster's periodogram appealed to him with great force. The light curves of variable stars he had already subjected to periodic analysis. He now attacked the elusive problem of the sun-spot periodicities, forcing the Sun to take its place as a variable star. Everything was pressed into the service, ancient Chinese records of spots, the ring-growth of Californian trees, the Leonid meteors, the longest series of meteorological records that could be found. No stone has been left unturned, and if in the end the key has not been found, it has at least been made clear that the secret of the underlying mechanism must be sought on quite different lines. Turner himself, both in the case of the Sun and in the case of variable stars, recognised his failure to establish the existence of permanent periodicities, and substituted a doctrine of "discontinuities" dividing a series of phenomena into separate "chapters." To those who welcome evidence of failure in the theory of determinism, Turner's work in this field should prove a mine of suggestion. But there is nothing to show that he himself was tempted to entertain this facile way of escape from the difficulties lying in his path. To the end nothing cooled his ardour in the pursuit of periodicities wherever they might be so much as suspected to exist.

So great is the volume of his work published through the normal scientific channels, apart from all other calls on his time, that it is not surprising if Turner's publications in ordinary book form are of minor importance. They comprise *Modern Astronomy* (1901), *Astronomical Discovery* (1904), *The Great Star Map* (1912), and *A Voyage in Space* (1915), the last containing the substance of a very successful course of Christmas (1913) lectures delivered at the Royal Institution. To single out one, *Astronomical Discovery* is a book so excellent in its kind that regret may be felt that no other opportunity presented itself for the same display of the author's charming style and characteristic lightness of touch. Turner went far to refute the Byronic aphorism that easy writing means cursed hard reading. In his case facile and rapid writing entailed no loss of lucidity or of a certain distinction of style.* These qualities are reflected in his fluent handwriting; thought and hand alike required space for their expression. In verse he is not known to have attempted anything more serious than light-hearted parodies. These were strictly *vers d'occasion*, to be sung by himself in congenial company; none could so well as he *desipere in loco*. Unpretentious as these efforts were, they were no disgrace to one who had been an intimate of J. K. Stephen at Cambridge. Before leaving this imperfect account of Turner's astronomical work, mention may be made of one project which did not come to completion. This is the book which would have contained the substance of his lectures to undergradu-

* Beyond the characteristic instinct for the right word, Turner's felicity in the coining of a new term deserves notice. The word "parsec" may be quoted as a contribution to the universal language of astronomy.

ates at Oxford. It is perhaps the single instance where a desire for perfection, combined of course with other occupations, held him back till it was too late. A small collection of *Examples on Heat and Electricity* (1885) was perhaps the first of all his publications and the only one of its kind.

In this place it is hardly necessary to describe in full detail the work which Turner undertook in connection with seismology, though some account of it must naturally be given. It may have been partly responsible for the important share he took in the affairs of the British Association. He was President of Section A in 1911 * and one of the two General Secretaries of the Association from 1913 to 1922. But at a much earlier date, 1898, he had become a member of its Seismological Committee. Still earlier Turner had formed a close friendship with John Milne, a friendship destined to influence his future to an extent he could not have imagined in its early days.

John Milne, who had been for twenty years professor of geology and mining engineering at Tokio, returned to this country in 1895 and took up his residence at Shide in the Isle of Wight. In the same year the Seismological Committee of the British Association was formed, superseding two existing committees on kindred subjects. Milne, who became at once its active spirit, had devised a simple undamped form of seismograph, and instruments of this type were distributed to a growing circle of stations. Besides maintaining one such station in full activity at Shide, Milne performed the function of a central organisation for the others, collecting reports, issuing circulars, and making such general discussions as the results suggested. It was a labour of love, in which he employed the devoted services of S. Hirota as assistant; the expenses, quite considerable in amount, were mainly defrayed by himself. Meanwhile, in 1907, Turner had succeeded Judd as chairman of the Seismological Committee, Milne remaining as secretary till his death in 1913 at the age of sixty-two. His demise created a most perplexing situation. Milne had been a man of leisure, with the means to gratify his hobby, and there was no one to take his place. Were the fruits of his labour to be lost? To Turner this was unthinkable; loyalty to his friend forbade it. He was himself fully occupied in other directions, and he had no private purse on which to draw. But the work must be carried on at all costs. A Royal Society grant had in the end provided for the small salary of Mr. Hirota, who died in 1913 some months after his return to Japan. The work at Shide was carried on, with periodical visits from Oxford and under increasing difficulty due to the War. The return of Mrs. Milne to Japan brought this phase to an end, and it was decided to transfer the instruments, now of the improved type introduced by Mr. J. J. Shaw, to Oxford. A temporary home was found in the Clarendon Laboratory owing to the failure of other plans. The change was completed in 1919, and it was only later, in 1927–28, that an extension of the University Observatory made it possible for Turner to concentrate all his work under one roof.

* Turner's presidential address on this occasion may be recommended as a significant declaration of his scientific creed.

Turner was determined that every part of Milne's work should be continued. This meant not only the routine of an ordinary seismological station, with incidental researches on points of general interest, but the reception of reports from a world-wide chain of stations and the preparation and periodical publication of a Summary based upon them. Such a programme naturally involved immense labour for himself in supervision, and heavy expense to be covered by very small assured funds and uncertain grants. This incessant financial struggle was the heaviest part of his burden, for it was not in his nature to spare himself toil or to ask whether his duty to astronomy had the prior claim on his energies. Turner was President of the Section of Seismology in the International Union of Geodesy and Geophysics, and delivered the opening addresses in that capacity at Rome (1922), Madrid (1924), Prague (1927), and at the fatal meeting at Stockholm last year. From the Union he drew an annual grant which, through unfortunate circumstances, proved inadequate to cover even the expense of printing the Summary. The decision to establish the Central Seismological Bureau at Strasbourg was a disappointment to him, to which he was only partially reconciled by the recognition of the International Summary prepared at Oxford. The difficulty in obtaining necessary funds was an ever-present anxiety and was temporarily evaded from time to time by advances from his own pocket. One consolation he had in what he felt to be an ungrateful world, the sympathetic support and liberal generosity of Dr. J. E. Crombie, of Dyce, Aberdeen, to whom seismology owes a unique debt.

Such were the circumstances which deflected a part of Turner's energies from the pursuit of astronomy in the last seventeen years of his life, though the remainder, faithfully devoted to his original duties, would have done no discredit to a less active man. Beyond the regular determination of epicentres, the subject of depth of focus was one which particularly engaged his attention and determined his attitude towards the problem of revising the P. and S. tables which naturally confronted him in his work. His propensity for detecting periodicities found scope in earthquake phenomena, and he indicated and investigated periods ranging from 21 minutes to 284 years. He discussed the evidence bearing on the existence of a liquid core within the earth, and his last contribution dealt with the distribution of deep-seated earthquakes. But his greatest service must be recognised in having kept alive a world-wide organisation of seismological results through years of exceptional stress and difficulty.

Another useful step stands to his credit. In 1917 Turner called a conference at Oxford to consider means of promoting, in this country, the discussion and publication of geophysical investigations. This led to the formation of a committee of the British Association which arranged geophysical discussions held, by the courtesy of the Royal Astronomical Society, in the Society's rooms. Later the Society itself undertook the organisation of these discussions, and also instituted the publication of *Geophysical Supplements to the Monthly Notices*.

Even from a bald account of Turner's scientific work it cannot fail

to be seen that his activity in research must have left him little opportunity for leisure. Yet as a professor in the University, as a Fellow of New College, and as a friend of many individuals and causes, he either had or assumed duties which he interpreted in the most liberal and comprehensive spirit. His statutory duties as professor may have been light, but many time-consuming tasks fell to his lot, such as the arrangements for the Halley Lecture and honorary degrees. The cause of the Workers' Educational Association and Tutorial Classes appealed to him strongly, and led him to give many lectures in all parts of the country. During the War he had lectured to the soldiers behind (and not far behind) the lines in France. His sympathy with University Extension in its widest sense led him to become an active member of the delegacy concerned with this phase of studies. The Oxford and Cambridge School Examination Board also enlisted his services, and as inspector in mathematics at several public schools his help was highly appreciated. A number of his lectures were delivered at Clifton, Rugby, and elsewhere, and undoubtedly fostered an interest in astronomy. As he grew older, in Oxford itself Turner's popularity certainly increased, chiefly but not entirely among the younger men. In his earliest years at Oxford Turner lived in New College, and even after his marriage dined frequently and entertained many guests there. From the first he took an active share in the social and business sides of the college. He was the trusted friend of the Warden, Dr. Sewell and Canon Spooner successively, and served his turn as Sub-Warden. A great college is usually a landlord, with landed estates to administer, and Turner played his part with zest in assisting the Warden on the Annual Progress and establishing human relations with the college tenants. Similarly he made a point of playing cricket in an annual match with the choir boys. His helpfulness to his colleagues, without thought of time or trouble, will remain a memory, and there is abundant testimony that Turner justified in an exceptional degree the arrangement by which a university professor is also a fellow of a college. He enjoyed the amenities of the position and gave much in return. Music was among his recreations, and he was a keen member of the Oxford Bach Choir.

The keynote of Turner's life lay in his energy, that vital force which failed him only in the moment of his death. Work was his passion, work in the mass. Idleness was intolerable to him always, and with advancing years the habit of work became only more exacting. Apart from those scientific missions which took him often to all parts of the world, such as the visit to the American Association at New York in the winter of 1928–29, Turner's holidays in the ordinary sense were few, short, and partial, for the mornings were generally devoted to work. A railway journey was an opportunity for reading proofs. When work was not pressing, though this must have been rare, he threw himself with equal ardour into the pursuit of games, golf, hockey, or even cricket; or, it might be, a ride on a bicycle. Such men enjoy life to the full, though it would be a mistake to suppose that Turner's habitual cheerfulness never failed him, for he was sensitive and felt disappointments keenly.

As his own energy was inexhaustible, so hard work by others elicited his sympathy and all the help and support that he could give, regardless of his own interests. His friendship with John Milne has been mentioned. Another and earlier friendship with A. A. Common will be recalled. There was a natural affinity in this case on the side of personal tastes. Both were keenly alive to the possibilities of new instruments, and their bold advocacy, coupled with Common's practical skill, had much to do with the adoption of the cœlostat, the Cambridge *coudé*, and the less successful Durham almucantar. It was a happy combination of complementary qualities, for Turner had little developed sense for practical design and mechanical detail.

His circle of friends was world-wide, and his extensive correspondence, in dealing with which he was assisted by his wife in later years, made a serious inroad on his time daily. He was equally accessible to those who approached him personally in search of advice, and in all such cases the time and trouble taken to elucidate some difficult point of astronomical or general scientific interest was not to be measured by mere interviews or letters. This incessant occupation of various kinds may have tended in the end to blunt his scientific susceptibilities to finer points, but never his sympathies. The effect of Turner's friendships survived the death of one partner in them, and loyalty remained a potent force through the rest of his life. He was equally tenacious of his resentments, and it is to be feared that his failure to obtain a residence at the University Observatory, though it led to no neglect of his astronomical duties, did colour his view of his relations to the University. As an energetic man of quick decision, he did not always see the full consequences of a given act, and was far from appreciating the tact and patience which are sometimes necessary in an imperfect world.

Among the many honours which fell to his lot, Turner may well have set the highest store on the Bruce Medal of the Astronomical Society of the Pacific, for his relations with American astronomers were always particularly intimate and cordial. The award was also a mark of appreciation for work done under the cloudy skies of Oxford from colleagues more favourably situated. He was elected to the Royal Society as early as 1897 and served on its Council. He was a corresponding member of the Paris Academy of Sciences from 1908; also of the Società dei Spettroscopisti Italiani. He received the honorary degree of D.Sc. from Leeds, Strasbourg, Sydney, and Wales, of D.C.L. from Durham, and of LL.D. from California. He married in 1899 Agnes Margaret, daughter of Robert Whyte of Blackheath, who with one daughter survives him. The loss of his vivid personality leaves a blank in the whole world of astronomy which will not readily be filled.

H. C. P.

Dr. William Wilson was born at Kendal on 1853 January 2. The fourth son of William and Hannah Wilson, he was educated at the Friends' School at Stramongate and at Grove House, Tottenham, from which he proceeded to Middlesbrough to qualify himself for the profession of civil engineer. Shortly after completing the course, he

offered himself to the cause of foreign missions. Being advised to qualify as a medical missionary, he proceeded to Edinburgh, where in 1881 he took the degrees of M.B. and C.M. A year later he sailed for China, destined to begin work in the city of Sian—famous for its Nestorian monument—in the province of Shensi. But owing to the hostility of the people of this city, he was forced to move on to the city of Hanchungfu, which was to be the centre of his labours for the next eleven years. Despite the difficulties of obtaining medical supplies so far from western civilisation, he overcame every obstacle by utilising and adapting native products and materials in the most ingenious way. Dr. Wilson had a quick eye for any new advance in missionary enterprise, and he soon saw that Christian truths could be brought home to the Chinese mind more efficiently by the use of Chinese art. So a Chinese artist was engaged to illustrate the Parables with Chinese pictures. For example, the Prodigal Son was shown leaving home in his sedan-chair, and the father's feast of welcome on his return was celebrated with chopsticks and everything else *à la chinoise*. After the Boxer troubles, Dr. Wilson transferred his sphere of activities to Szechwan in West China. About this time a wave of intense interest in western knowledge began to sweep over the Chinese student world, and by means of lectures on scientific subjects Dr. Wilson succeeded in getting into touch with a class of men who would otherwise have been wholly unapproachable. In 1908 he moved to Chentu, but three years later the heavy strain of his multifarious labours proved too great and he was compelled to leave China for good.

While in retirement at Hampstead he invented an orrery for use in schools and colleges. This was patented in 1916 and later put on the market. A demonstration, which was given in the Society's apartments, of Dr. Wilson's ingenious mechanism brought forth the hearty approval of our leading astronomers, and educationalists all over the country were quick to see its possibilities in demonstrating the different phenomena associated with the movements of the bodies in the solar system.

Dr. Wilson was twice married; his first wife was Miss Catherine Goodman of Blackheath, by whom he had two sons and four daughters, two of whom became foreign missionaries; his second wife was Miss Elizabeth Hanbury, who predeceased him by a little over a year. He died at Boscombe on 1930 February 8.

He was elected a Fellow on 1917 December 14.

Captain Hugh Montague Wood was born in London on 1886 September 28. Apprenticed to Watson Bros. of Glasgow in 1903, he made his first voyage in the sailing ship *Ben Avon*, which was wrecked off Palliser Bay, near Wellington, N.Z. The crew were saved with the utmost difficulty. He served in various ships trading in the east and notably in the S.S. *Otaki*, which during the war was attacked by the German raider *Moewe*, and after severe fighting was sunk. The survivors of the crew were taken prisoners and were kept in various prison camps in Germany for the remainder of the War. While a

prisoner of war, Captain Wood met Captain Thornton, a colleague in the Merchant Navy, and they started classes in navigation, which were much appreciated by young officers in the same unfortunate predicament. Returning to England after the armistice they founded the "Thornwood Nautical School." During 1919 Captain Wood wrote a series of articles on the "Deviascope" which were published in the *Nautical Magazine*, and later in book form with the title *The Deviascope Simplified*. Another book—*Ship-handling Simplified*—was finished just before his death, and is now in course of publication. Captain Wood was an enthusiastic angler. In 1913 he married Edith Theodosia, elder daughter of H. Herrington of St. Albans. He died at Bexhill on 1930 August 6, and is survived by his widow and one son.

He was elected a Fellow on 1926 June 11.

Alfred Ernest Young was born at Seaham Harbour on 1869 February 4. He was educated at the City and Guilds of London Institute, and in 1892 received an appointment in the Trigonometrical Survey Department of Perak (one of the States afterwards included in the Federated Malay States). After about twenty years' service there, by which time he had become Deputy Surveyor General of the Federated Malay States, he was obliged to retire on account of ill-health. In 1899 he read a paper before the Society "On the Formulæ of Reduction to the Meridian of the Observed Zenith Distances of Stars" (*M.N.*, **59,** 532). In 1907 the Fellowship of the City and Guilds of London Institute was conferred on him for his valuable and original work, particularly in connection with the Trigonometrical Survey of the Malay States. After his return to this country he was engaged in assisting Professor Turner at Oxford in the measurement of stellar photographs. While at Oxford he prepared for publication a paper on "The Form of a Suspended Tape, Including the Effect of Stiffness," which was printed in the *Phil. Mag.* (1915 January). This work was ended by the outbreak of war. During the War he was employed for some time by the Government in the preparation of maps. In 1920 he published a book, *Some Investigations in the Theory of Map Projections* (R.G.S. Technical Series, No. 1), and in 1927 the Royal Geographical Society conferred on him the Gill Memorial Prize for his development of the mathematical theory of map projection. In 1921, his health having improved, he was appointed Surveyor General of Jamaica, but only remained there about a year as his health again broke down. After that he devoted himself to the study of the mathematical theory of map projection, and in 1930 he attended the conference of the International Union of Geodesy and Geophysics held at Stockholm, where he read a paper on "The General Conformal Projection." Besides his connection with the Royal Astronomical Society and the Royal Geographical Society, he was an Associate Member of the Institution of Civil Engineers, to which society he contributed several papers in his early years.

He died 1930 December 30, leaving a widow and two young children.

He was elected a Fellow of the Society on 1896 May 8.

Johann Georg Hagen was born on 1847 March 6 at Bregenz, on the eastern shore of the Lake of Constance, in the neighbourhood of which his family had lived for two centuries. He began his noviciate with the Jesuits at the age of sixteen. He showed a marked taste for scientific studies, and was allowed to carry these on, first at Münster under Heis, afterwards at Bonn University. During the War of 1870 he was sent to France for tending the sick and wounded, but he caught typhus and was invalided for several months. He afterwards resumed his scientific and mathematical studies till 1875. He then came to Ditton Hall, near Liverpool, for his theological studies and was ordained priest in 1878. In 1880 he was sent as a teacher to Prairie du Chien, Wisconsin. He established there a small observatory and began the study of variable stars. In 1888 he was appointed director of Georgetown College Observatory, Washington. He now enjoyed the use of a 12-inch equatorial, with which he continued his work on variable stars, and began his important publication, the *Atlas Stellarum Variabilium*. This was published in successive instalments, Series I. to VI. appearing between 1899 and 1908, VII. in 1927, and VIII. was awaiting publication at his death. The series are graded by magnitude, V. consisting mainly of naked-eye stars. In all cases a sufficient number and range of comparison stars are given to cover all the stages of variation. Father Hagen himself determined the magnitudes of the comparison stars by the step method. He also published between 1913 and 1921, *Die Veränderlichen Sterne*, Band I., "Geschichtlich-technischer Teil." This has been described as "a historic encyclopædia of variable stars." A second volume, by Father Stein, Hagen's successor at the Vatican Observatory, appeared in 1924.

In 1906 Hagen was summoned to Rome by Pope Pius X., at the suggestion of Archbishop (afterwards Cardinal) Maffi; he was shortly afterwards appointed Director of the Vatican Observatory. This was enlarged by the addition of the Leonine Tower, which had been used by Pope Leo XIII. as a summer residence. This tower is 1000 years old, and so massively constructed that it permitted of the erection of a 16-inch equatorial refractor on its summit without any supporting pillar. The astrographic refractor is on another tower at some distance, the two being connected by a raised walk.

The astrographic work on the zone 55° to 64° N. Decl. was vigorously pushed forward; the plates were taken by Father Lais, the measures were made by the nuns of a neighbouring convent, and the reductions were in large part carried out at the Oxford University Observatory, Professor Turner having offered his help after the Oxford zone had been completed. The publication of the measures of the zone (in ten volumes) was completed in 1928.

Hagen used the 16-inch refractor for the study of nebulæ; his plan was to observe the brightness of all those contained in the N.G.C. He brought out in three parts (1922, 1925, and 1927) a Preparatory Catalogue for a Durchmusterung of Nebulæ. During the War, when the night sky of Rome was unusually dark, he began to notice that extensive clouds of faint luminosity were visible in various regions of the heavens;

some of these corresponded with the regions already recognised as covered with obscuring clouds, so that the latter seemed to give a little light. Hagen communicated several papers to the Society on these faintly luminous regions. There is fairly general agreement that some of them are real, but others, where photography shows nothing, are disputed. Professor Hartmann has suggested that they may be composed of interstellar sodium gas, the yellow colour of which would not have much effect on ordinary plates.

Many Fellows will recollect Father Hagen's hospitality at the I.A.U. Meeting in Rome in 1922. Father Stein, in a notice in *Astr. Nach.*, 5744,* which has been of much help in this notice, says : "Feinde hat dieser immer friedliche und freundliche Priester wohl keine gehabt, aber Freunde und Verehrer zahllos viele."

On the attainment of Hagen's eightieth birthday in 1927 he was honoured by a visit from Pope Pius XI., who presented him with a special gold medal in recognition of his services to astronomy. The Society sent him a congratulatory letter on this occasion, which caused him much gratification.

Father Hagen's health began to fail in 1930 March ; he rallied during the summer, but in August was moved to the Quisisana Sanatorium, where he died on September 5 at the age of eighty-three.

He was elected an Associate of the Society on 1908 June 12.

A. C. D. C.

* Acknowledgments are also made to Miss Alice Farnsworth's notice in *Publ. Ast. Soc. Pacific*, 1930 October.

Proceedings of Observatories.

The following reports of the proceedings of Observatories during the past year have been received from the Directors of the several Observatories, who are alone responsible for them.

Royal Observatory, Greenwich.
(*Director, Sir Frank Dyson, K.B.E., Astronomer Royal.*)

Transit-Circle.—The number of transits observed during the year was 11,377, including 123 of the Sun and 90 of the Moon. The observations are reduced to 1925·0 as far as 1930 September. The ledgers of clock, azimuth, and zone stars are complete to the end of 1929. The observation of all stars down to magnitude 8·0 and between declinations + 32° and + 64°, begun in 1922, was completed on December 31. During the nine years about 10,500 stars were observed five times each, out of a list of approximately 10,800, the remainder being observed four times each.

A new zone catalogue of stars between the equator and declination + 24° was commenced on 1931 January 1. It contains roughly 6000 stars and comprises all stars of visual magnitude 7·5 and brighter. In some regions it extends to magnitude 8·0. The additional list of reference stars for Eros prepared by Dr. Kopff will be observed early in the present year.

Altazimuth.—This instrument has not been in use in 1930.

Cookson Floating Zenith Telescope.—During the year 228 plates were obtained for variation of latitude, and 9 for determination of scale. The number of plates obtained in the different months were :

January	16	May	13	September	13
February	15	June	25	October	20
March	22	July	19	November	14
April	22	August	33	December	16

28-*Inch Refractor.*—During the year 345 measures of 251 double stars were secured. Arranged according to separation they are :

Under 0″·5	54	observations.
0″·5–1″·0	100	,,
1″·0–2″·0	128	,,
Greater than 2″·0	63	,,

A new electric motor for the purpose of rotating the dome has been recently installed.

26-*Inch Refractor.*—The work on stellar parallaxes has been continued and 1285 plates have been obtained during the year. 755 plates have been measured. The parallaxes of 33 stars have been published

in the *Monthly Notices* for 1930 November. In November and December the instrument was mainly devoted to the observation of Eros, and 78 plates of Eros were obtained.

30-*Inch Reflector*.—The work on colour temperatures of stars has been continued. Two additional stars (γ Orionis and β Canis Minoris) have been added to the list of standards, and 19 comparisons of these with other standard stars have been secured. In addition, 48 comparisons of 22 other stars with one or more of the standards were obtained.

The comparison between the standard stars and laboratory sources of known colour temperature has been begun, and some preliminary results obtained. The positive crater of a carbon arc is being used as an intermediary, and in connection with this work a series of comparisons between the arc and a standard acetylene flame of colour temperature 2360° K is being obtained in the laboratory.

To facilitate the measurement of the spectra, a self-recording photo-electric microphotometer has been purchased from the Cambridge Instrument Co., Ltd., and brought into use.

Astrographic Equatorial.—During the year 25 fields were photographed through the glass for the determination of proper motions of stars in the Greenwich Astrographic Zone. 74 plates of fields in zones + 75° to + 85° were measured. Zone + 75° has now been completely photographed and reduced.

The instrument has been employed for the photography of Eros since 1930 October 9. 164 plates were obtained previous to the end of the year.

The telescope was under repair and out of use over the period January 21 to April 30.

Photoheliograph.—Photographs of the Sun were obtained on 256 days at Greenwich and on 346 at the Cape. On ten days, photographs were not taken at either observatory, but for seven of these days plates are available from Kodaikanal. For 1930 the mean daily spotted area, corrected for foreshortening, was approximately 500 millionths of the Sun's hemisphere—a considerable decrease as compared with the preceding year. The published values for the years 1924–29, since the last minimum, are 276, 830, 1262, 1058, 1390, and 1242 respectively.

The spectrohelioscope lent by the Mount Wilson Observatory was in use throughout the year, observations being made on 135 days. Attention was given mainly to the measurement of radial velocities of bright and dark $H\alpha$ flocculi, especially those near the centre of the Sun's disc. Unusual activity was observed on August 12 and November 25, the radial velocities of the dark $H\alpha$ markings on the latter date reaching 450 km./sec. outwards from the Sun. Notes on these eruptions are given in *Monthly Notices*, **90**, 820 and **91**, 239, 1930.

Clock and Time-Service.—The free-pendulum clock Shortt No. 3 was substituted for Shortt No. 11 as standard sidereal clock on April 1. No. 11 has been kept going as reserve standard and regular comparisons are made with No. 3. An experimental pendulum fitted with a plain steel suspension spring and an invar bob has been ordered from the

Synchronome Co., Ltd. It is intended to substitute this on one of the standard sidereal clocks for the purpose of investigating the cause of the retardation of rate found in the free-pendulum clocks.

The mean time free-pendulum clock Shortt No. 16 has controlled all mean time clocks used for time-signal distribution throughout the year. The transmission of wireless time-signals through Rugby and the B.B.C. stations, in addition to the service of hourly telegraph signals, has been maintained regularly.

The reception of wireless time-signals from Rugby, Nauen, Annapolis, and Bordeaux stations has been maintained, and the results of the comparisons circulated in *Notices to Mariners.*

Observations with Transit B.—Observations for clock correction were made on 61 nights.

Observations of Eros.—These observations were commenced early in October, and a large number of plates were taken in October and November with the astrographic equatorial. In December the weather was unfavourable, and on very few nights were photographs obtained at considerable hour angles on both sides of the meridian.

Printing.—The volume of Greenwich Observations for 1928 and its separate parts have been distributed, and the proofs of Greenwich Observations for 1929 have been passed.

Miscellaneous.—In September Lieut.-Commanders L. C. Woodhouse and A. Jones, R.N., made a series of observations with the 45° astrolabe of Captain Baker's design, and obtained extremely satisfactory results.

Professor Lundmark was at Greenwich in December engaged in the examination of nebulæ on the Franklin-Adams plates.

Mr. A. de Sitter came to Greenwich on December 2 and has been taking part in the work of the observatory.

Royal Observatory, Edinburgh.
(*Director, Prof. R. A. Sampson, F.R.S., Astronomer Royal for Scotland.*)

The delivery and erection of the 36-inch reflector was begun in May and occupied about 7 weeks. The separate castings and parcels, consisting of portions not exceeding about one ton in weight, were lifted by a crane on to the flat roof, and were then handled with a run-way carried between gantries erected one within the dome and the other upon the roof, the dome being opened in the proper direction to allow a free run. By this method all the major parts were safely and rapidly set in place, and the telescope completed and connected according to plan, except for the spectrograph. Since then prolonged tests and adjustments of the various working parts have been made, chiefly by Professor Sampson and Mr. Storey, leading to numerous improvements in minor features that concerned smooth working. Probably these will continue until they merge in the ordinary care of a working instrument.

As the spectrograph was not delivered at the same time, a counterpoise to replace it was made and attached, permitting the use of a

camera. With this, specimen stellar fields have been photographed in different circumstances and much information obtained.

At the date of writing Messrs. Hilger, Limited, have still not delivered the spectrograph, an accident to the heating control having delayed it.

In the other departments of the observatory the work has proceeded upon the same lines as heretofore.

Time has been determined with the transit-circle on all nights that permitted it, and wireless records of the times from Rugby, Bordeaux, Nauen, and Annapolis have been made. The reception has been satisfactory and normal. The chronographic system within the observatory has been unchanged; temperature control of the clock cells has been improved and apparently brought to a final state by passing only a very small current through the thermometers used for detection, employing an enclosed mercury contact for the relay and rearranging the circuits accordingly, so as to run off the A.C. mains, with transformers and rectifiers. Strict control of the temperature has effected a great improvement in the clock Leroy No. 1230, which has performed admirably throughout the year. The clock Riefler No. 258 continues to give trouble by tripping seconds. The clock Shortt No. 4 has been run with a fused silica pendulum, replacing the invar rod. This experiment proved more interesting than was expected, for it greatly reduced, as well as made uncertain, the barometric equation upon which final adjustment of rate depended. The invar pendulum has now been restored.

A discussion of the whole series of stellar spectra taken for determination of stellar temperatures with the 6-inch photovisual and objective prism from 1923 to 1929 was completed and presented to the Society in 1930 May. The observations are now discontinued.

Photographs with the solar spectroscope for rotation of the Sun have been continued upon the same plan as in previous years.

Seismological and meteorological observations have followed the routine already established.

With regard to printing measures of astrographic plates taken at Perth, W.A., and treated here, a refusal, which must be taken as final, has been received to a request to the Treasury to provide the cost. It remains to be seen whether any other avenue is open.

Royal Observatory, Cape of Good Hope.
(*Director, Dr. H. Spencer Jones, F.R.S., H.M. Astronomer.*)

Reversible Transit-Circle.—The number of meridian transits observed during the year was 9088. The Sun was observed on 206 days, Venus on 142 days, and Mercury on 92 days. The observations comprise zodiacal stars and stars brighter than $7^{m}\cdot5$ south of $-30°$ Dec. This programme was commenced in 1925 and is nearing completion, though there remain a few poorly observed patches, particularly within the right ascension limits of the southern Eros reference stars.

A series of observations has been made to determine magnitude equation in right ascension and declination. The observations suffice to show that the magnitude equations are small, but a more prolonged series is required to reduce the probable errors of the derived magnitude equations.

Current reductions are well advanced, and the results up to 1929 January 31 have been entered into the ledgers.

A working list has been prepared of additional Eros reference stars required on account of the deviation of the path of Eros from the computed path. Observation of this list has been commenced.

8-*inch Transit Circle.*—Observations were commenced in June of a series of reference stars in the zone −30° to − 35° Dec., required for the reduction of photographs obtained with the 6-inch wide-angle triplet lens. The observations are being made by differential methods, the positions of the fundamental stars being based on observations with the reversible transit circle. Up to the end of the year the number of meridian transits which had been observed was 2959.

Zone Observations.—The wide-angle triplet lens of 6 inches aperture will be used first to photograph the zone − 30° to − 35° Dec. The observations have been postponed until after the completion of the Eros observations. The tests and adjustments of the camera have been completed. The investigation of the errors of the long screw measuring machine is well advanced.

Heliometer.—Observations of the major planets near opposition have been continued as follows :—

Opposition of Neptune	. 84 obs. in distance	on 7 nights.
„ „ Saturn	. 66 „ „ „	„ 6 „
„ „ Uranus	. 76 „ „ „	„ 6 „
„ „ „	. 12 „ „ position angle	„ 2 „

Victoria Telescope.—The telescope was in use on 251 nights during the year for stellar parallax determinations. 1953 plates were secured and 2020 plates were measured. The parallaxes of 63 stars have been derived and will be published shortly along with others which are now awaiting final reduction. The largest parallax, not previously known, is that of Co.D − 46° 11540, for which a value of $0''{\cdot}237 \pm 0''{\cdot}006$ has been obtained.

8 plates of the Pluto region were obtained in March and April. The derived positions of Pluto have been published in the *Ast. Nach.*

10 plate-holders have been constructed in the workshop in order to reduce the time required in changing plates.

Astrographic Telescope.—55 plates were taken along the path of Eros to provide material for deriving the positions of the secondary reference stars from those of the primary reference stars.

9 plates of Comet Forbes (1930*e*), 7 of Comet Schwassmann-Wachmann (1930*d*) and 1 of Comet Wilk (1930*c*) were obtained. The resulting positions of the comets have been published in the *Ast. Nach.*

Steady progress in the measurement for proper-motions on the photographs of regions in the Cape Astrographic Zones has been made.

During the year 683 plates were measured, either direct or reverse. The measures of the zones $-41°$ to $-49°$ inclusive, have been completed; zone $-50°$ is at present in hand. The reductions of the measures of zones $-41°$, $-42°$, $-45°$, $-46°$, and $-47°$ have been completed.

Nova Pictoris.—A full discussion of the spectra of Nova Pictoris has been made, based upon the spectrograms obtained with the 4-prism spectrograph in 1925–26, supplemented by a series of objective prism spectra obtained between 1925 and 1928 at the Union Observatory, and kindly loaned by Mr. H. E. Wood, Union Astronomer. The latter spectra cover the region from about λ3700 to Hα.

One result of interest derived from these plates is that, in 1928 October, a radiation of wave-length λ6087, of unknown origin and not previously observed in any nova or nebula, was stronger than any of the hydrogen radiations and was exceeded in intensity only by He^+, λ4686.

The discussion, which will shortly be ready for the printer, will be published in the *Cape Annals*.

Opposition of Eros.—As Chairman of the Solar Parallax Commission of the International Astronomical Union, H.M. Astronomer has been much occupied with arrangements for the observation of Eros near its opposition. Extensive co-operation has been promised. A co-operative scheme of observations near the meridian has been arranged between the Cape and Yale (Johannesburg) in the south, and Greenwich, Cambridge, Radcliffe, and Bergedorf in the north, using long-focus telescopes, and between the Cape and Harvard (Bloemfontein) in the south, and Greenwich, Bergedorf, Algiers, and Bordeaux in the north, using telescopes of astrographic scale. Observations at the Cape will also be obtained by the diurnal method, using both the Victoria and astrographic telescopes.

A wire-diffraction grating, with equal bar and space, has been made in the workshop for the astrographic telescope, to provide a control over the effective wave-lengths of the comparison stars used in the measurement of the Eros plates. The portion of the path of Eros accessible from the Cape will be photographed, using this grating.

Photoheliograph.—711 photographs were obtained on 343 days to supplement the Greenwich series. Visual observations for zero were made weekly. Original negatives to 1930 November 17 and duplicate negatives to 1930 October 17 have been sent to Greenwich.

Occultations.—7 observations of disappearance at the dark limb, 2 of disappearance at the bright limb, 4 of reappearance at the dark limb, and 1 of reappearance at the bright limb were made.

Night-Sky Observations.—Observations of the brightness of the night sky were secured on 185 nights, in continuance of the co-operative scheme arranged by Lord Rayleigh. The mean brightness for the year shows a decrease as compared with preceding years, which may be connected with the decrease in the sun-spot activity.

Time-Service and Wireless Time-Signals.—The emission of the international (Onogo) type of time-signal at 21^h G.M.T., on a wave-length of 625 metres, from the Slangkop wireless station, has been regularly con-

tinued. Commencing on 1930 July 1, similar signals are also regularly sent out at 7^h and 19^h G.M.T. on a wave-length of 36 metres. The emitting apparatus is controlled by a Shortt Synchronome free-pendulum mean-time clock.

The following observations of the scientific rhythmic signals sent out from Bordeaux and Rugby were obtained during the year :—

		No. of Days.
Bordeaux	8^h	231
,,	20^h	26
Rugby	10^h	243
,,	18^h	32

Cambridge Observatory.
(*Director, Sir A. S. Eddington, F.R.S.*)

During the greater part of the year the Sheepshanks telescope has been used for photo-electric work. Trial has been made of a new method of measurement with apparatus devised by Mr. E. B. Moss of the Cambridge Instrument Co. ; this is described by him in a paper published by the Physical and Optical Societies (Discussion on Photo-electric Cells). The new method surmounts many of the difficulties that had been experienced, but greater sensitivity is still very much desired.

Photographic observations of Eros were begun in the middle of November, but owing to the extremely unfavourable weather, practically nothing of value was secured up to the end of the year. Plates were taken on four nights, only one of which was clear throughout. The conditions in January have been better.

It was found in July that the surface of the flint lens of the Sheepshanks object-glass had begun to deteriorate, and that the film could not be removed without refiguring. As this would take some months, it was decided not to proceed with it until after the opposition of Eros. The loss of light at that time was not large, but it has since become much worse ; and in spite of further cleaning in November the work on Eros has been handicapped both by the necessary lengthening of the exposure time and by the difficulty in finding guiding stars.

Six pairs of plates have been measured for proper motion. Results of measurement of plates, taken by Dr. Knox-Shaw, for the determination of colour index in connection with the Cambridge proper motions, have been communicated to the Society (*M.N.*, 1930 June).

Mr. R. D. H. Jones, B.A., Sheepshanks Exhibitioner, has been working on the statistics of proper motions under the direction of Dr. Smart. Mr. J. C. P. Miller, B.A., Isaac Newton Student, who had been absent for eighteen months through illness, resumed his connection with the observatory at the end of the year. Dr. G. C. McVittie has worked in conjunction with the Director on the problem of the " expanding universe " ; he left Cambridge in June to take an appointment

at Leeds University. Professor W. E. Anderson of Miami University, Ohio, spent the first six months of the year in astronomical work in Cambridge.

Considerable repairs to the fabric of the main building were carried out in the long vacation, and the interior has been redecorated.

Solar Physics Observatory, Cambridge University.
(*Director, Professor F. J. M. Stratton, M.A.*)

Staff.—During the year Dr. J. A. Carroll has resigned on being appointed Professor of Natural Philosophy in the University of Aberdeen. Dr. R. O. Redman, Astronomer at the Dominion Astrophysical Observatory, Victoria, has been appointed to succeed him as Assistant Director. Dr. J. C. Dobbie has been appointed as a Junior Observer.

Professor Wilson and Mr. Dee have continued their work with the expansion chamber at the observatory, and Mr. H. C. Webster of the Cavendish Laboratory has commenced a study of the artificial production of nuclear γ rays by α-particle bombardment of light elements, work which requires freedom from radium contamination. Spectroscopic facilities have also been given to Mr. Sutherland of the Physical Chemistry Laboratory for work on Raman spectra and isotopes, using the 21-foot Rowland concave grating and the microphotometer.

Mr. E. G. Williams has nearly completed his study of the contours of hydrogen lines in the spectra of stars of different temperatures and surface gravity : 140 spectrograms have been secured for this purpose with the Newall 25-inch refractor and the Huggins 15-inch refractor ; 160 records have been taken with the microphotometer.

Mr. A. W. Mailvaganam, Emmanuel College, has commenced the investigation of the radiation emitted from a tube of sodium vapour stimulated by the passage of a beam of incident light.

Instruments.—The recording microphotometer referred to in last year's report has been received and taken into use. A full description of the instrument has been published by the Society (*M.N.*, 1930 November).

The spectroheliograph was dismounted from June 4 to August 18 for reconstruction on the designs of Professor Newall, who has kindly continued his co-operation in this work. For the spectroheliograms in K light, single lenses made by Messrs. T. Cooke & Sons were substituted for the compound lenses previously in use, and two prisms of 60° angle put in place of the former single prism of 45°.

A temporary curved secondary slit was used during the last few months of the year, but new curved primary and secondary slits are now being constructed to avoid the distortion of the solar image. Provision is also now made for obtaining a spectroheliogram in Hα light using the same collimator but reflecting the beam on to a plane grating. A new single lens of 3·5-inch aperture and 58-inch focal length has been supplied by Messrs. T. Cooke & Sons for the camera for the Hα image. Provision has been made to place a Fabry-Pérot interferometer in the optical

train for a study of motion in the line of sight in disturbed areas on the Sun's surface.

A thermostatic temperature control is being constructed for the spectrograph of the Huggins refractor.

The Hills siderostat with 12-inch silver-on-glass mirror has been installed in a small shed on the north side of the laboratory, and the 21-foot Rowland concave grating and other laboratory instruments can now be fed by it with solar light. For work admitting of moderate dispersion a small concave Rowland grating, received from the Salomons bequest, is being installed so as to be available for the same light sources as those employed for the standard 21-foot mounting.

New lenses of focal length 12 inches and focal ratio 4·5 have been obtained from Messrs. Aldis Bros. for a new spectrograph for the 3-foot Common reflector ; lenses of focal length 12 inches and focal ratio 3 have been obtained from the same firm for a spectrograph for use with the 20-inch Common mirror of focal length 50 inches, which has been lent to the observatory by the Joint Permanent Eclipse Committee. The mirror has been sent to Messrs. Grubb, Parsons & Co. for refiguring. It is proposed to erect a building for the instrument in the field to the south of the laboratory.

Buildings.—A new shed with lean-to garage has been built during the year. A new electric installation has been laid throughout in connection with a change in the town supply to a 3-phase system. Power and light are now available separately in all the buildings. The workshop has been enlarged and concrete pillars have been erected in the laboratory for optical instruments and in the spectroheliograph shed for a spectrohelioscope.

Spectroheliograph.—Owing to the loss of the summer months and a large proportion of bad weather in the other months, the observations for the year were much below the average in number. Photographs of the sun's disc in K_{232} light were obtained only on 36 days, and photographs of the prominences on the Sun's limb on 27 days.

For the year 1929 October 1 to 1930 September 30, the Director of the Kodaikanal Observatory has sent 325 spectroheliograms of the Sun's disc in K_{232} light. Bromide prints of 194 photoheliograms from negatives taken at Greenwich, the Cape, and Kodaikanal Observatories have been received from the Astronomer Royal for the period 1928 July to December. A further investigation of the development of bright calcium faculæ is in preparation by Mr. Butler, and will shortly be communicated to the Society.

Solar Radiation.—Preliminary observations have been made with a thermocouple in the focal plane of the Cooke 59-foot object-glass of the McClean solar installation, in preparation for a comparison of the total radiation from selected small areas of the Sun's surface.

Laboratory Investigations.—An attempt to identify some unknown lines in the spectrum of α Persei has led to the discovery of a number of lines in the spectrum of the pole of an iron arc run with a low current. These are being generally investigated and their relations with the ordinary polar lines of the arc are being examined.

Meteorological Physics.—The study of the electric fields of thunderstorms has been continued with an improved electrometer. A considerable number of records have been obtained and are being discussed. The results of the investigation of the discharge of electricity from an elevated metal point during periods of disturbed weather conditions have been published (*Proc. R.S.*, **127**, A, 567).

Volume II. Part I. of the *Annals* of the observatory was published during the year.

Dunsink Observatory.
(*Acting Director, Mr. Charles Martin, M.A.*)

The time-service to Dublin has been continued as in previous years. The meridian circle has been used only for time determination.

The observatory has been used mainly for teaching purposes, students being welcome in the day for instrumental instruction, and any clear evening for observational work.

University of Durham Observatory.
(*Observer, Mr. Frank Sargent.*)

During the year the work of observing the set programme of long-period variable stars has been carried out, 602 observations having been made. The daily meteorological observations have been duly recorded and forwarded to the Meteorological Office.

The work on the newly installed Milne-Shaw seismograph has proceeded steadily and records are now being regularly taken.

Investigations are being made with a view to obliterate, if possible, the effects of certain microseisms which in some cases mar the value of the records.

The observer has also co-operated with other institutions in making special observations of meteors.

The director, Mr. Harold Thomson, having expressed a wish to retire, a small committee, chosen from the members of the Board of Curators, has been placed in executive control of the observatory.

Imperial College Observatory, South Kensington.
(*Director, Asst. Prof. H. Dingle.*)

The observatory has been open as usual mainly for the instruction of students, but the exceptionally bad weather has prevented much effective work from being done. Both demonstrators have left during the year: Dr. L. J. Freeman has been appointed to a lectureship at Chelsea Polytechnic, while Dr. R. W. B. Pearse, having been awarded a Commonwealth Fund Fellowship, has taken up spectroscopic work at the Norman Bridge Physical Laboratory, Pasadena. Mr. A. S. M. Symons has been appointed to succeed Dr. Freeman. Laboratory

investigations in various branches of spectroscopy have been continued. The equipment has been increased by the purchase of a recording micro-photometer from the Cambridge Scientific Instrument Co., and further additions which are expected shortly are a Fabry-Pérot interferometer from Messrs. Adam Hilger, Ltd., and a spectrometer of special design bequeathed by the late Col. Gifford. In addition to the following papers published during the year, several investigations are in progress —in particular, the determination of accurate wave-length standards in the extreme ultra-violet, by Professor Fowler, who is also engaged in the study of problems of combustion and of the still unknown bands in the spectra of comets. The results, however, are not yet ready for publication.

Assistant-Professor H. Dingle: "The Spectrum of Ionised Fluorine (*F* II.)" (*Proc. Roy. Soc.*, A, **128**, 600).

Dr. L. J. Freeman: "The Spectra of Trebly-Ionised Oxygen (*O* IV.) and Trebly-Ionised Nitrogen (*N* IV.)" (*Proc. Roy. Soc.*, A, **127**, 330).

Mr. C. V. Jackson: "The Spectrum of Silicon Hydride" (*Proc. Roy. Soc.*, A, **126**, 373).

Dr. R. W. B. Pearse: "The λ3400 Band of Phosphorus Hydride" (*Proc. Roy. Soc.*, A, **129**, 328).

Dr. K. R. Rao: "The Spectrum of Doubly-Ionised Arsenic" (*Proc. Phys. Soc.*, **43**, 68).

Mr. J. S. Badami: "The Spectrum of Trebly-Ionised Cerium" (*Proc. Phys. Soc.*, **43**, 53).

Mr. T. E. Nevin: "Band Systems Associated with Selenium" (*Nature*, 1930 July 5).

Liverpool Observatory and Tidal Institute.
(*Director, Prof. J. Proudman; Associate Director, Dr. A. T. Doodson.*)

The tide-predicting machine, which was purchased last year from the executors of the firm of E. Roberts & Son, has been erected with numerous additions and improvements. It has been in regular use since early in 1930, with very satisfactory results. An undulator has been purchased and installed, with the object of receiving wireless messages in Morse code. The Lancaster clock, which controls the time-scale of the seismometer records, has undergone considerable repairs.

Tidal predictions of high and low water have been made for 64 places; of hourly heights of water for 2 places; and of times of slack water for 3 places. Records of tidal observations from 27 places have been analysed. Tidal charts of the English and Irish Channels, showing co-tidal and co-range lines for the principal harmonic constituent, have been constructed for the Hydrographic Department of the Admiralty, and researches relating to the dynamical theory of the tides have been continued.

The regular meteorological service of observations and transmission of information has been continued unbroken, and the time-gun has not failed during the year.

Visits of inspection were paid to the observatory by the Acting Conservator of the River Mersey and by the Hydrographer of the Navy. Dr. Doodson has been awarded the Thomas Gray Memorial Prize of the Royal Society of Arts for his work on the analysis and prediction of tidal currents. Professor Proudman attended, as a British delegate, the meeting of the International Union for Geodesy and Geophysics, which was held at Stockholm.

University of London Observatory, Mill Hill, and University College Observatory.
(*Director, Professor L. N. G. Filon, F.R.S.*)

Co-ordinates of the Observatory.—Attempts to fix the precise position of the observatory on an ordnance map having failed through the absence of any easily recognised marks in its vicinity, the Ordnance Survey were approached. After some correspondence with them on the matter, it was decided to determine as accurately as possible the co-ordinates of the intersection of the axes of the Wilson reflector. The work was carried out in April with a Zeiss theodolite, and the deduced position, stated to be accurate to within a foot, is as follows :—

Long. 0° 14′ 26″·50 W.
Lat. 51° 36′ 46″·28 N.

The altitude was determined with an ordinary level, a bench-mark being fixed to the wall of the observatory, the height of which on the Liverpool Datum was given as 255·5 feet, and the corresponding height of the point of intersection of the axes of the reflector, 266·5 feet.

The Wilson Reflector.—This instrument has been in use throughout the year, and has been working in a satisfactory manner. Photographs with exposures up to two hours have been taken of nebulæ ; also a number of comets and the recently discovered planet, Pluto, have been photographed. A lantern slide of the last-named was shown at the April meeting of the Society. Some trouble was experienced from street lighting in the vicinity of the observatory, which caused fogging of the plates during long exposures. This trouble, however, has now been practically overcome by fitting opaque screens to the lamps in question, kindly provided by the Hendon Urban District Council. Most of the plates were taken by Mr. C. C. L. Gregory, the Wilson Observer, and a few by Miss V. White and Mr. C. V. C. Herbert.

A movable observing platform, designed by the Wilson Observer, was constructed in the observatory workshop to allow of easy access to the principal focus for guiding during long exposures. The arrangement works in a highly satisfactory manner for all zenith distances up to 50 degrees, beyond which an ordinary step-ladder may be used.

The Rowland Grating Spectrograph and the 8*-Inch Cœlostat Telescope.*

—This combination of instruments has been used chiefly for work on the sun, in conjunction with an electric furnace. Most of the plates were taken by Miss E. Williamson. This work was interrupted in June by the observer's ill-health. The spectrograph, in spite of being well lagged, was found to suffer in definition in the case of long exposures. Accordingly, at the end of the year a toluene thermostat was fitted, which is now working in a satisfactory manner. The acquisition of this piece of apparatus was due to the generosity of Miss Williamson.

New Instruments.—At the beginning of January Mr. H. R. Fry, of Barnet, presented to the observatory his 8-inch Cooke equatorial refractor, together with a sum of money towards its reconditioning and re-erection. The instrument was reconditioned in the observatory workshop, and was erected during the summer vacation in a small brick observatory, specially designed to take a second-hand dome which was purchased from Messrs. C. Baker. This dome was removed in sections from the 50-foot tower of a house at West Wickham, in Kent, and re-erected under the supervision of Mr. C. C. L. Gregory, the work being executed by Messrs. Leslie & Co. This observatory is provided with a Synchronome clock dial, controlled by the sidereal clock of the main observatory, the transmission being effected through overhead wires, as is also the 240-volt A.C. service supply for lighting the observatory and energising the transformer to provide current for the low-voltage lamps which illuminate the various circles and micrometers on the instrument.

During the latter part of the year, a Littrow spectrograph of 6 inches aperture was built in the workshop and erected for use with the cœlostat telescope, to be used alternatively with the Rowland grating. The prism of this instrument is the property of University College, and is the one referred to in the annual report of that observatory for 1928. The 6-inch achromatic lens has been kindly lent to the observatory by Mr. Planck, at the suggestion of Mr. Frank Robbins. This instrument is also lagged, and may be kept at a constant temperature by means of the toluene thermostat.

A high-frequency amplifier is in process of construction for use with photo-electric cells. Most of this work is being done by Mr. Herbert, a research student. Mr. Herbert has presented some valuable laboratory apparatus and chemicals to the observatory.

Occultations.—Five occultations were observed during the year, the reductions of which are nearly completed.

Visitors.—The observatory has been open to members of the public as usual on the first and third Wednesdays of the month, between 2.30 and 4.30 p.m., and two Saturday evenings per month near the time of full moon have been devoted to local residents, who have applied in writing to the Director. 253 visitors have availed themselves of the opportunity to visit the observatory.

University College Observatory.—The work, which is mostly instructional, has been carried on as in previous years. It was found necessary to take down and recondition the $3\frac{1}{2}$-inch transit circle by Cooke. The work was carried out in the College workshop, and the

instrument has now been fitted with an impersonal micrometer by Casella, which may be used alternatively to the system of fixed webs. The Grubb chronograph has also been reconditioned, and repairs have been done to the shutters in the roof of the observatory.

Radcliffe Observatory, Oxford.
(Director, H. Knox-Shaw, Radcliffe Observer.)

During the year 33 plates were taken of the Selected Areas for proper motion, and of these 21 have been passed for measurement. Ten other plates were exposed; 2 of these were for the determination of magnitude error; 4 on Pluto, which were measured and the results communicated to the Society; and 2 on the Pleiades for comparison by Professor Hertzsprung with plates taken here twenty-three years earlier. There remain to be taken 54 plates of the proper motion programme; the great majority of these are on the areas in R.A.'s between 3^h and 13^h. Measurement and reduction have now caught up observation, 29 plates having been measured during the year. The reduction of 71 out of the 115 areas of the systematic plan has been completed. Definitive values for the correction on account of magnitude error have been adopted, and these are now being applied to the results for the areas so far reduced.

The computation connected with the reduction of Hornsby's observations was completed in the summer, and the work is in process of being written up.

Dr. Steavenson spent five months in South Africa testing the seeing at a site on the hills near Pretoria, with very satisfactory results. The Director joined him there in June, and consulted an architect about plans for the buildings. The Municipality of Pretoria has very generously offered to present the site to the Radcliffe Trustees, but the future of the observatory is still undecided, the only thing that is settled being the fact that it must vacate its present site by the summer of 1935.

University Observatory, Oxford.
(F. A. Bellamy, M.A., *Director, pro tem.*)

The past year has been a sad one for this observatory, and for Astronomy in Oxford. For thirty-seven consecutive years the late Professor H. H. Turner wrote the annual report upon the year's work; this temporarily devolves upon me.

The work, mentioned in the last report, for the Vatican zones of the Astrographic Catalogue, $+64°$ to $+55°$, of the tabulation of the corrections to the Helsingfors A.G.C., and the discussion for proper motions, etc., was completed last October by Miss Bellamy and myself, and the MS.—about 900 pages—awaits printing by the Vatican Observatory. But the remarkable coincidence of the deaths of the Directors of both observatories within a few days of each other has somewhat delayed the printing being proceeded with. This obser-

vatory has been closely engaged with the Vatican zones of the Astrographic Catalogue for Father Hagen for nearly twenty-five years (all the reductions and examination of all the proof-sheets for the ten volumes were accomplished here).

When approaching the termination of our participation in the Vatican zones, Professor Turner, as Chairman of the Carte du Ciel Commission of the International Union, having ascertained that the zones originally allotted to the Potsdam Observatory would not now be completed, eventually succeeded in getting the four northern zones, + 36° to + 39°, undertaken at H.H. the Nizam's Observatory at Hyderabad, and we agreed to do the other four zones, + 32° to + 35°, which adjoin the former Oxford section, one degree overlapping the Oxford + 31° zone.

This work has been proceeded with at all available opportunities, the computations of Turner's standard co-ordinates and other parts have been made to a considerable extent, 60 plates have been exposed, about 40 have been measured. But help for measuring and simple computations is greatly needed; the staff is very small for such an ambitious piece of research. If financial aid be forthcoming I think all might be completed within five years. This scheme, together with Seismology, now fully occupies the staff at the observatory.

Papers have been written and printed in various publications during the year by Professor Turner, Dr. Fotheringham, and by F. A. and Miss E. F. Bellamy. Besides that, much time has had to be given to the collection and writing of notes upon the Professor's work, extended to nearly fifty years, in response to requests. A good deal of unfinished work, in more or less advanced stages, has been left by Professor Turner, chiefly upon harmonic analysis, discontinuities and periodicities in various phenomena; also in his analysis of star counts and in seismology. This seems inevitable with one who always carried on so many investigations simultaneously.

In the Seismological department all the work has proceeded regularly on former lines, the loss of the Professor's help being greatly felt. The continual increase in the number of stations naturally tends to require more time for the collection of the data and the preparation of the MS., and for proof-reading; also the cost for printing is much increased thereby. As an indication of this increase and expense, it may be mentioned that the results for 1925–26 (12 months) required 360 pages of close print, while for 1926-27, 485 pages have been required, which represents the amount done in 1930. The MS. for 1927 July–September is nearly completed for press. The 35th report of the Seismological Committee to the British Association was written by Professor Turner, but he did not live to read it at the Bristol meeting in September. He had also prepared a memorandum as to the unsatisfactory financial position of the Seismology section in this country, for communication to the International Union which met at Stockholm last August. No funds, except a partial amount for printing, had been received from the Union since the formation of that body, about 1919; the severe task of getting even the minimum amount of money required

to carry on the seismological work of collecting and tabulating the records had been left to Professor Turner, who for at least ten years was continually striving to get the money from various sources. Had it not been for Dr. J. E. Crombie's most generous help and sympathy for several years the continuance of the work in this country and as a memorial to John Milne must have failed ; but failure in another direction resulted, as the constant strain upon him in his efforts to obtain those necessary funds, materially broke down his health and terminated in his own death, while still striving for the proper maintenance of the Seismological Department. May one express the hope that this be made the occasion for a memorial in this country, perpetuating his and John Milne's work in that branch of Science ?

The pier, referred to in the previous report, which was in its construction isolated from the surrounding concrete floor in the Crombie Basement of the new building, has continued to give trouble by its unsteadiness, mostly in extreme wet and dry weather. In order to ascertain if close association of the pier with the concrete floor would overcome these movements, an experiment is being tried by wedging in bricks at certain points, so that the pier and floor form a united mass. The experience so far gained indicates a marked improvement, but the period is too short ; it has not run through all changes of weather. The other instrument (E/W) remains on a temporary pier of stone resting on the concrete floor and near the south wall ; that is usually very steady during October to March, but becomes very disturbed from April to October by the sun shining upon the gravel and ground outside.

Norman Lockyer Observatory, Salcombe Hill, Sidmouth.
(*Director, William J. S. Lockyer, M.A., Ph.D., Major (late R.A.F.).*)

The 9-inch Kensington prismatic camera has been in regular use throughout the year, for the purpose of photographing the spectra of stars showing bright hydrogen lines and of the Orion nebula. The Zeiss triplet lens attached to this instrument has also been used, chiefly for the photography of star regions. Occasional photographs have been taken with the fixed meteor camera, and with a Zeiss triplet which has also been erected for a similar purpose. The 12-inch McClean prismatic camera has been in use during a portion of the year, mainly for the routine photography of the spectra of B-type stars for parallax work, or for obtaining spectra of stars showing peculiarities.

The number of fine nights during the year was below the average, being only 118, which is 23 less than the previous year and 12 less than the average annual number. Successful observations were made on 104 of these nights. The number of negatives secured with the Kensington instruments were : 180 with the 9-inch prismatic camera, 29 with the Zeiss triplet for star regions, 10 with the fixed meteor camera, and 4 with the new Zeiss meteor camera. On the night of 1930 Nov. 25 a good meteor trail was shown crossing both the fields of the two cameras. The plates were each exposed from $17^h\ 50^m$ to

$27^h\ 45^m$ U.T. With the 12-inch McClean prismatic camera 80 negatives were secured.

Work has been continued on B-type stars with bright hydrogen lines in their spectra. The results of a prolonged study of the star HD 20336 Camelopardalis were presented to the Society at the December meeting. Several stars have been discovered to possess previously unrecorded bright lines, and the spectra of two of these have been described in the *Monthly Notices*, **91,** 187, 1930. A paper on monochromatic images of the Orion nebula was published in *Monthly Notices*, **90,** 580, 1930. The work on spectroscopic parallaxes is also being continued. A list of 175 parallaxes of B-type stars was published in *Monthly Notices*, **90,** 523, 1930, and more negatives taken since that date are available for this work and for the study of peculiarities in B-type spectra.

The electric wiring of the two domes has been adjusted in order to utilise the main supply of the observatory directly for the work of pendulum control and field illumination in the telescopes, thus obviating the use of small auxiliary accumulators. The Mond astrographic equatorial, which is under construction at Messrs. Cooke, Troughton & Simms's works, is expected to be delivered during the middle of next year. Work on the erection of the dome will be commenced early next year.

Four mounted photographs were specially prepared for the 75th annual exhibition of the Royal Photographic Society ; they included prismatic camera spectra of the Orion nebula and bright hydrogen-line stars, and a photograph of the clepsydra instrument for broadening stellar spectra.

The observatory is open to visitors on Wednesday afternoons, and the number who attended during the year was 290, including members of the British Association, the University College of the South-West, and other special parties. In addition, the observatory was opened to the public on two evenings (which, fortunately, were both fine), when a charge was made in aid of the local hospital, and a total of 493 visitors attended.

The fourteenth annual general meeting of the Norman Lockyer Observatory Corporation was held in London on June 12.

Stonyhurst College Observatory.
(*Director, Rev. E. D. O'Connor, S.J., M.A.*)

We have lost the services of the Rev. D. R. Ward, who left the observatory in August for his theological studies. The Rev. T. Corbishley is assisting in the meteorological work. Otherwise the staff remains unchanged.

The meteorological, magnetic, and seismological records have been maintained as usual, and the results forwarded to the official centres. Absolute measures of the horizontal magnetic force and of the inclination have been made once each month, and the declination has been observed once each week. Continuous records of the variations of

declination and horizontal force by the photomagnetographs have been maintained throughout the year; but the vertical force balance, which had become inoperative owing to the cumulative effect of secular variation in declination, was dismounted in June. It is hoped to devise some modification in mounting by which this instrument may be again brought into service.

The work on synoptic meteorology has been continued, and a daily weather forecast for the district issued in the *Lancashire Daily Post*.

Observations of the solar surface were made on 266 days, and include 264 drawings. Of these, 235 are complete, showing all spots and faculæ, whilst of the remaining 29, 11 are complete for spots. The mean daily spotted area (in units 1/5000 of the disc) was 2·25 as compared with 6·19 in 1929 and 7·19 in 1928.

Sunspot statistics have been sent regularly to Professor Brunner of Zurich for the preparation of the "Sunspot Numbers," published in the quarterly *Bulletin* under the auspices of the I.A.U., and charts of the solar surface for each rotation have been drawn showing all spots and faculæ, together with reduced copies of the horizontal force magnetograms, for facilitating the study of the relation between solar phenomena and terrestrial magnetic conditions. We have to thank Professor Brunner of Zurich and Professor Favaro of Catania for having very kindly put their solar drawings at our disposal, to fill in the gaps in our own observations, so that the charts may be made as complete as possible.

The weather during the year has been very unfavourable for astronomical observations. Of the 82 lunar occultations listed in the *Nautical Almanac* as visible at Greenwich, all except 10 were unobservable owing to bad weather or clouds. 8 observations were successfully made—5 disappearances and 3 reappearances—and the results forwarded to Dr. Comrie.

26 out of the 52 Herschel nebulous fields have been examined, each two or three times, and a start has been made to attempt to photograph them with the 6-inch Dallmeyer portrait lens working at F/4, and a Wratten No. 16 filter; but so far without success.

The instruments have been used occasionally for educational purposes both for the boys of the school and for visitors, and the Director has given a number of public lectures during the year.

Dominion Observatory, Ottawa, Canada.
(*Director, Mr. R. Meldrum Stewart.*)

Meridian Work and Time-Service.—In the regular programme work of the meridian circle there were obtained, on 195 observing days, 3103 observations for right ascension and declination of stars, and 178 of the sun, moon, and planets. On 27 nights, observations for clock correction were made also with the 3-inch Cooke transit. The time service was maintained as in previous years with no material changes. Wireless time-signals were received regularly from Rugby, Annapolis,

Bordeaux, and Nauen, the reception being made by coincidence by extinction, and, when convenient, by registration. Time-signals were broadcast at 3 p.m., except Sundays, through radio station CNRO on concert wave-length, and daily through the observatory station on 40·8 metres.

Solar Physics.—The programme of solar rotation determination was continued and some 240 nine-strip spectrum photographs about λ5600, recording centre, midway, limb, and iodine absorption were made, and about 350 measurements and computations. Direct photographs of the 9-inch solar image were made (daily when possible) to the number of 194. A very striking relationship to the fluctuations of sunspots was found in some Manitoba records of numbers of grasshoppers, two kinds of grouse, and varying hares. The sunspot effects are so profound that a great number of tree sections were secured from various parts of Canada in order to investigate the relationship and the change of phase for different regions. The sections have been photographed and a number of these have been measured. A second preglacier spruce reveals the sunspot cycle, as did an earlier specimen.

The 15-inch Equatorial.—Radial velocity work on spectroscopic binaries was continued. In all, 297 spectrograms were obtained. The stars chiefly studied were ϵ Aurigæ, η Virginis, ζ Ursæ Majoris, and χ Draconis. Several complete series of spectrograms were measured and the orbits computed. In particular, η Virginis proved to be of special interest, its orbit exhibiting marked variations both in period and eccentricity over a range of several years. A Moll microphotometer was obtained and its installation completed. The telescope was, as usual, made available to visitors every clear Saturday evening; on cloudy evenings lantern slides were shown.

Photographic Photometry.—The preparation of charts of the revised list of Cepheids was continued, all but one of the fields being photographed and charts forwarded to Harvard. Observations have been continued also for the determination of the light curves, 360 plates being obtained. Tables were completed for the prediction of occultations by a semi-graphical method, and occultations visible at Ottawa were computed for 1931.

Seismology.—During the year 317 earthquakes were registered, of which 11 were reported to the Press and 13 by telegraph to Science Service at Washington, D.C. With the exception of the year 1928, the number of recorded earthquakes was less during 1930 than for several years previous. The one major earthquake of the year occurred on July 14 and originated near Central America. The seismographs at Ottawa, Halifax, and Saskatoon, as well as the short-period instruments at Shawinigan Falls and Seven Falls, were in practically continuous operation throughout the year. The investigation of the earthquake of 1925 March 1 was completed. Work on the Grand Banks earthquake of 1929 November 18 is under way. A study of the Tango earthquake of 1927 March 7 has also been undertaken.

Terrestrial Magnetism.—Magnetic work during the year 1930 was confined to the occupation of repeat stations for secular change of the

magnetic elements. The total number of stations at which observations were made was forty-seven. These, with the exception of three northerly stations, namely, The Pas, Mile 200 (H.B. Ry.), and Churchill, are distributed over the areas lying between longitudes 75° W. and 116° W., and the Canada-United States boundary and latitude 53°.

Gravity.—Following a lapse of two seasons, the field work in connection with the gravity survey of the country was resumed with the occupation of thirteen stations in Eastern Canada. In continuation of the investigation of the application of geophysical methods of prospecting, torsion balance surveys were made of one ore body and two faults in the vicinity of Ottawa. Surveys with magnetic variometers were made of three ore bodies and three typical geological structures in different parts of the country.

Publications.—Eight of the regular series of publications were issued during the year: Vol. 7, No. 5, *The Location of Epicentres*, 1926–27; Vol. 8, No. 10, *Magnetic Results*, 1924–26; Vol. 10, Nos. 2, 3, 4, 5, 6, *Bibliography of Seismology*; Vol. 11, No. 1, *Wireless Time-Signals observed at Ottawa*, 1921–26.

Dominion Astrophysical Observatory, Victoria, B.C.
(*Director, Dr. J. S. Plaskett, F.R.S.*)

The permanent observatory staff has remained unchanged during the past year, although Dr. Redman has accepted the assistant directorship of the Solar Physics Observatory, Cambridge, and will leave here in February. Professor H. H. Plaskett of Harvard University and Professor P. ten Bruggencate of Greifswald, Germany, each spent about three months during the summer, obtaining observational data for later discussion. Professor Plaskett investigated several planetary nebulæ spectro-photometrically, with special reference to the intensity of the continuous hydrogen spectrum beyond the Balmer series, and also the relative intensities of the emission lines. Professor ten Bruggencate obtained the radial velocity curves of two Cepheids, impressing also spectro-photometric standards on the plates for the determination of the total absorption of characteristic lines at various phases.

The observing weather for 1930 while somewhat poorer than the preceding year was nevertheless considerably above the average. Thus 1088 spectra were obtained in 1415 observing hours on 217 nights as compared with a twelve-year average of 1518 spectra in 1272 hours on 206 nights, while in 1929, the best year on record, 1224 spectra were obtained in 1487 hours on 226 nights. In all, 1143 spectra were measured for radial velocity during the year. The observatory open nights have been continued as in previous years and the interest has been well maintained. It is estimated that, including both day and night visitors, over 33,000 persons visited the observatory during the year.

The Director was absent nearly four months in the eastern part of the United States and England, giving several addresses on various phases of the work, including, as the most important, the George Darwin

lecture on "The High Temperature Stars." The remainder of the time has been occupied in collaboration with Dr. J. A. Pearce in the completion and preparation for publishing of the previously unpublished individual observations of O to B5 stars, which have been under observation at Victoria since 1923. Vol. 5 of the Observatory Publications is to be devoted exclusively to the high temperature stars; and No. 1, which is in press, contains the individual radial velocities from 3047 measures of 2679 spectra of 523 stars, of which 124 are new spectroscopic binaries discovered at Victoria. Much time was spent on the preparation of a general catalogue of all published radial velocities of O to B5 stars, the greatest care being taken to obtain as accurate and homogeneous velocities as possible, and to weed out from the announced binaries those which more experience indicated as probably of constant velocity. In this catalogue, which is Vol. 5, No. 2, of the Observatory Publications and is also in press, there are 1601 determinations of the radial velocities of 1006 stars in which no less than 15884 spectra have been used. Of these 1006 stars 318, over 30 per cent., are now definitely assigned as having variable velocity. Vol. 5, No. 3, on the interstellar diffuse matter with a catalogue of all stars known to have interstellar lines and a full discussion of all results, is in preparation.

Mr. W. E. Harper has continued the observation of the programme of A-type stars with some attention to orbital determinations of spectroscopic binaries. Altogether he obtained 379 spectra, mostly of A type, during the year, of which about 20 were of stars previously unobserved, the remainder being additional plates of stars observed earlier. About 500 spectra were measured for radial velocity and the orbits of 5 binaries determined and published. In addition, a revision of the orbit of one star, *b* Persei, was obtained. The observation of the programme of A stars is nearly completed, and the measurement and reduction of the radial velocities is well up to the observations.

Dr. J. A. Pearce, in addition to full collaboration with the director on the B-type programme, has carried through a complete set of solutions for the solar motion, galactic rotation, and K term for all the O to B5 stars with reliable velocities, and a further set with the new solar motion for the galactic rotation and the K term. These results will appear in vol. 5, No. 4. A complete set of graphs to read off directly the component of the solar velocity towards any star has been prepared in collaboration with Mr. S. N. Hill.

Dr. C. S. Beals has continued observation of the long-period variable Z Ursæ Majoris, and that part of the radial velocity curve accessible in the winter and spring has been reasonably well covered. Spectrophotometric observations of the intensities of the interstellar calcium and sodium lines have occupied a large part of the observing time during summer and fall, although some observations have been made for the purpose of studying spectro-photometrically the contours of Wolf-Rayet bands and the intensities and contours of P Cygni lines. In collaboration with Dr. Redman, apparatus has been arranged for conveniently impressing on each stellar spectrum plate accurate photometric standardization. This is done by the use of an auxiliary

spectrograph with a neutral tint wedge, the calibration of which has involved considerable labour and time. In the laboratory the wavelengths of oxygen and nitrogen lines in the stellar region have been redetermined and the results prepared for publication.

Dr. R. O. Redman has completed the spectroscopic work on Y Cygni, the results being in very satisfactory agreement with Dugan's photometric observations. There is evidence for a third body in the system which is probably responsible for the observed rotation of the line of apsides. Preliminary calculations of the solar motion and galactic rotation were made from the radial velocities of about 200 galactic K-type giants of apparent visual magnitude 7·0 to 7·5. The elements so obtained, although subject to some uncertainty on account of the large peculiar velocities of these stars, were in very fair agreement with conclusions drawn from other sources. Observations of these stars have been continued, and now some 400 radial velocities are available, covering practically all the K stars within the selected limits of magnitude and position. Much attention has been given to the systematic and accidental errors of these determinations. Spectroscopic observations of the semi-regular variables SV Ursæ Majoris and V Ursæ Minoris were undertaken during the spring. The radial velocities are high, about −102 and −171 km. per sec. respectively, while the velocity variation is small.

Mr. S. N. Hill has determined the spectroscopic orbit of H.D. 32990, and has assisted in the measurement and computation and tabular work required in the preparation for publication of the Victoria B-type velocities, and also in the preparation of the general catalogue. He has collaborated with Dr. Pearce in the preparation of the graphs of solar velocity above referred to, and besides has carried on other computing work.

There have appeared and been distributed during the year *Publications*, Vol. 4, Nos. 16 to 18, while Vol. 4, Nos. 15, 19 to 21, Vol. 5, Nos. 1 and 2, and Vol. 6, No. 1, are in press. Several articles in astronomical periodicals have also appeared during the year. The weekly meetings or seminars of the staff have been successfully continued, about fifty reviews of outside contributions and of our own work having been given.

Helwan Observatory, Ministry of Public Works, Egypt.
(*Director, Mr. P. A. Curry.*)

Time-Service.—The time-service was maintained as usual, and the error of the standard clock, Shortt No. 1, has been determined daily from the Bordeaux and Rugby rhythmic wireless signals. The clock has run well throughout the year without any attention, its general behaviour being similar to that of the previous year. The average change of rate throughout the year was $0^{s}\cdot001$ a day, the greatest change being in June when it reached $0^{s}\cdot01$ per day over a period of 4 days.

The new reversible transit was only used on 18 nights as the mounting of the spirit level was not satisfactory. This has now been overhauled,

and it is hoped that regular transit observations of a high order of accuracy will be resumed next year.

Reynolds Reflector.—The telescope was used on 79 nights, 79 plates were exposed, 15 on various comets, 26 on planet Pluto, 36 on nebulæ, and 2 focus plates. 23 plates on Pluto and 3 on Tempel's second periodic comet were reduced by the method of dependences, the results being published in the cards of the Bureau Central Astronomique.

General.—The usual meteorological, magnetic, seismological, and solar radiation observations were made.

Mr. A. Samaha, B.Sc. (London), joined the observatory in July as assistant astronomer.

Nizamiah Observatory, Hyderabad.
(*Director, Mr. T. P. Bhaskaran, M.A.*)

Astrograph.—The astrographic equatorial was in regular use throughout the year and 128 plates have been obtained for the Catalogue in the regions of the old Potsdam zones, and for revision of the early plates in the Hyderabad series. A few plates have also been exposed on Eros during November and December. 96 Catalogue plates were measured during the year and 10 repetition plates for the determination of proper motions.

It is proposed to add to the equipment a Blink comparator for facilitating the comparison of photographs; a machine has been ordered and is expected to be received early in 1931.

Vol. vii. of the Hyderabad Astrographic Catalogue (Dec. $-23°$) has been published and copies were distributed in October 1930. The MS. of vol. viii., dealing with some discussions of the work as a whole, is under preparation.

The 15-inch Grubb Refractor.—Regular observations of variable stars have been continued and 1088 estimates of visual magnitude were obtained during the year. The working list comprises 61 long-period variables, which are very faint at minimum, and 9 irregular variables. The weather conditions were unfavourable for work during a large part of the year.

Observations of some of Herschel's fields of nebulosity have been made when the sky has been exceptionally good.

Fifty-six occultations of stars by the Moon were observed:

Disappearances	47
Reappearances	9

Time.—Observations with the transit instrument were made once a week on the average for determining clock corrections.

Seismology.—The Milne-Shaw seismographs (both components) have been in operation during the year without much interruption, and the total number of shocks recorded was 138. The readings of the seismograms have been communicated to the University Observatory, Oxford.

Daily observations of the upper air by means of pilot balloon flights have been continued in co-operation with the India Meteorological Department.

The usual meteorological observations and other routine duties have been carried on as in previous years.

Kodaikanal Observatory.
(*Director, T. Royds, D.Sc.*)

Photoheliograms were obtained on 330 days, calcium flocculi plates on 327 days, calcium prominence plates on 299 days, *Hα* flocculi plates on 292 days, and *Hα* prominence plates on 272 days. One calcium flocculi plate for each day was sent to the Solar Physics Observatory, Cambridge, as in former years.

Under the auspices of the International Astronomical Union, prominence and *Hα* flocculi spectroheliograms were collected from other observatories whenever complete observations were not possible at Kodaikánal. The statistical data regarding prominences seen at the limb and by absorption on the disc are published in half-yearly bulletins. Data for *Hα* prominences at the limb as well as calcium prominences are now included in the publications.

Daily character figures for solar activity according to *Hα* bright flocculi and *Hα* dark markings have been communicated to the Observatoire Fédéral, Zürich, for publication.

A Lummer-Gehrcke plate of quartz, measuring 200 × 30 × 8 mm., and an electromagnet have been added to the laboratory equipment.

The Director has prepared a bulletin, now in the press, on the rotation and height of *Hα* absorption markings from spectroheliograms of the four years 1926–1929. The mean height of the highest portion of an absorption marking is found to be 33″·5 above the chromosphere, and of the lowest portion 28″·0. This evidence proves that the lowest parts of prominences seen at the limb do not show by absorption (of *Hα* light) when on the face of the sun.

Dr. Narayan has photographed spark spectra of *Tl* and *Pb* with a view to identification of lines due to successive stages of ionisation. He is studying the iron lines in different parts of the electric arc by means of the Lummer-Gehrcke plate. He has also begun preparations for investigating the magnetic fields in sunspots.

Mr. P. R. Chidambara Iyer has found that one-day sunspots are less frequent between longitudes 30°–50° from the central meridian. The effect is less marked for spots of longer duration.

Mr. Salaruddin has measured two years' plates for the average change in the projected areas of *Hα* dark markings as they cross the sun's disc.

Mr. A. S. Rao, Madras University Research Scholar, has prepared his M.Sc. thesis on the spark spectra of lead from work carried out at the Observatory.

The Director was on leave until 23rd April, and Dr. A. L. Narayan officiated as Director during the period.

Union Observatory, Johannesburg.
(Union Astronomer, Mr. H. E. Wood, M.Sc.)

$26\frac{1}{2}$-*Inch Grubb Visual Refractor.*—The year's work comprises :—

Double Stars.—3524 measures of double-stars (including the 9-inch measures) ; 69 new pairs discovered.

Photographs of Double Stars.—35 plates with multiple exposures.

Saturn's Satellites.—40 measures of Mimas ; 55 measures of Enceladus ; 83 measures of Tethys, Dione, Rhea ; 18 measures of Titan as a double.

Eros, 1930–31 *Opposition.*—5 measures.

Variable Star.—A variable star with a period of 100 minutes, discovered by van Gent, was observed visually on one night for 2 hours by Hertzsprung, van Gent, and van den Bos. The period and light-curve of the star were confirmed.

The year 1930 was not favourable as regards definition and, as most of the good nights had to be used for Mimas and for measuring difficult double stars, few definitive searches could be made.

Franklin-Adams Star Camera.—During the year, 1328 plates were obtained with this instrument, distributed as follows :—

Minor planet regions and star maps . . .	360 plates.
Variable star regions	891 ,,
Comets	77 ,,

443 measured positions of minor planets have been forwarded to the Astronomisches Rechen-Institut.

Comet 1930 *d* (Schwassmann-Wachmann) was observed photographically from 1930 June 3 to August 24 : Comet 1930 *e* (Forbes) from June 2 to June 13 : Comet 1930 *f* (Tempel (ii)) from August 26 to December 21.

With the new 10-inch photographic telescope attached to the Franklin-Adams mounting, 122 plates were obtained during the year.

Occultations of Stars by the Moon.—The programme of the last few years has been maintained without alteration. Predictions are made graphically for the disappearances, at about first quarter, of all stars in the moon's way for which positions are given in the A.G. Catalogues : for those stars for which the elements are given in the *Nautical Almanac*, predictions are made by Dr. Comrie's semi-graphical process, and as far as possible the occultations of all such stars are observed.

During the year 1930 the number of occultations observed was 196.

The results of the year's observations are as follows :—

	s	″
1930·1	10·7	5·8
·4	12·1	6·6
·6	10·4	5·7
·9	9·3	5·1

The second column indicates the time by which the moon has arrived too early at any longitude, and the third column the distance the moon is ahead of its tabular longitude.

Time-Service.—Throughout the year time has been taken from the rhythmic signals sent out from Rugby, England, at 10^h U.T.

9-Inch Grubb Refractor.—This telescope is now used mainly for observations of occultations of stars by the moon, eclipses of the satellites of Jupiter, and measures of the wider double stars. One evening a week is set apart for visitors, the total number of visitors during 1930 being 1440.

Opposition of Eros, 1930–31.—Observations of Eros were commenced on the morning of 1930 December 22, when the declination of the planet was still 34° N. Up to the end of the year 5 visual measures have been obtained with the 26½-inch refractor, and 9 multiple exposure plates with the Franklin-Adams II. telescope.

Union Observatory Circulars.—During the year Circulars No. 81, 82, and 83 were distributed.

Of the Southern Star Maps, 22 were issued with these Circulars, and the present state of the project is therefore :—

Maps already issued	388
Maps in hands of Government printer	27
Maps still to be prepared	141
Total . .	556

Miscellaneous.—Dr. W. H. van den Bos was appointed Chief Assistant as from 1930 October 1.

Mr. H. van Gent of the Leiden Observatory has continued to use the Franklin-Adams Star Camera throughout the year for the photographic investigation of variable stars.

Professor E. Hertzsprung of Leiden Observatory arrived at the observatory on 1930 December 2.

Melbourne Observatory.

(*Director, J. M. Baldwin, M.A., D.Sc., Government Astronomer.*)

Astronomical observations have been limited to work with the 8-inch transit circle on the list of Fundamental Stars published in the *Connaissance des Temps* for 1914, and to observations of southern variable stars of long period. The results of the latter observations have been sent each month for publication in *Popular Astronomy.*

Owing to no money being available for publication, the printing of vols. 4 and 5 of the *Astrographic Catalogue,* zones − 70° to − 74° (both of which are ready for the printer) could not be proceeded with. The volumes of *Hourly Values of the Magnetic Elements at Toolangi in* 1928 also could not be printed for the same reason. In January the temporary computers—only two of whom remained—were transferred to other departments, so that no progress could be made on the later volumes of the *Astrographic Catalogue.* Quarterly seismological bulletins have been issued as in previous years.

Sydney Observatory.
(*Director, Mr. James Nangle, Government Astronomer.*)

The year has been uneventful, but steady progress has been maintained in carrying out the programme. Volumes xi. and xii. of the *Astrographic Catalogue* have been printed and distributed to the leading Scientific Institutions and Observatories. Volumes ix. and x. are in hand, and are nearly ready for the printer. It is hoped to have them completed and distributed during 1931.

No plate measures have been made for some time, there being enough completed to enable the transit observations to be used in the computation of the plate constants. The work of plate measurement will, however, have to be resumed early in 1931. It is hoped that this will be possible, even though the finances of the country are in a depressed state.

The astro-photographer will retire at the end of this year, and it may be decided to appoint, instead of a successor to him, an assistant to the transit observer. This will enable a greater progress to be made with work on the Catalogue. On the other hand, it may mean a suspension, for some time, of the photography for the Chart. The photography for the Catalogue has been completed.

The time-service and other routine work of the observatory have been carried out satisfactorily. One hundred and ten earth tremors were recorded on the Milne seismograph. Of these, two were records of very destructive earthquakes which occurred in Burma. A record was also obtained of a local disturbance in the Yass district of New South Wales—quite an unusual occurrence.

Public interest has been maintained in the observatory, there being no less than 904 visitors during the year.

The Dominion Observatory, Wellington, New Zealand.
(*For the Year* 1929.)
(*Director, C. E. Adams, D.Sc., Dominion Astronomer.*)

The time-service has been maintained, and the regular signals have been sent out. The signals have been transmitted daily. The total number of signals sent from the observatory was 1755.

The usual method of recording radio time-signals has been to use the chronograph with the hand key. This method will be supplemented by an entirely automatic one, by means of the Marconi magnetic relay which is now being installed.

Wellington General Post-Office Clock.—The Post-Office clock is checked at 3 p.m. on Mondays, Tuesdays, Thursdays, and Fridays by the broadcast signal through the station 2YA, Wellington. On Wednesdays, when station 2YA is not broadcasting, the clock is frequently checked by the signal heard through the air. This clock is not under the control of the observatory. The greatest errors were :—10 seconds slow on June 6, and 8 seconds fast on November 5.

Government Buildings Clock.—The Government Buildings clock has been kept under fairly close control. A record is obtained at the observatory by direct circuit from the clock, and the adjusting weights on the clock are altered from time to time. The greatest errors of this clock were:—28·65 seconds slow on July 4, and 37·25 seconds fast on February 15.

Summer Time.—The Summer Time Act, 1929, provided for the time in New Zealand being half an hour in advance of New Zealand standard time for the period beginning at 2 a.m., New Zealand standard time, on Sunday, 1929 October 13, and ending at 2 a.m., New Zealand standard time, on Sunday, 1930 March 16.

The following table gives particulars of the W/T time-signals received at the Dominion Observatory during the year 1929:—

Mean Time Signals.

Station.	Call Sign.	Hour, G.M.T.	No.
Honolulu	NPM (long wave)	00	284
Nauen	DFY ,, ,,	00	188
Malabar	PKX ,, ,,	01	156
Annapolis	NSS (short wave)	03	23
Arlington	NAA ,, ,,	08	133
Annapolis	NSS (long wave)	08	16
Bordeaux	FYL ,, ,,	08	59
Rugby	GBR ,, ,,	10	7
Bordeaux	FYL ,, ,,	20	29
		Total . .	895

Scientific time-signals were also received at the observatory as follows: Nauen 33, Bordeaux 2.

The radio time-signals received at the observatory generally agreed with the observatory clock within one second of time. Greater differences, however, have been observed in the following cases:—

	Differences from Observatory Clock.	
	From 1 to 2 seconds.	s. Over 2 seconds.
Honolulu, NPM	4 times	3·01 slow, Feb. 6
	..	7·99 slow, Feb. 26
	..	8·58 slow, Mar. 6
Nauen, DFY (mean time)	..	2·75 fast, Dec. 7
Nauen, DFY (scientific)	..	9·35 slow, on Nauen mean time-signal of Nov. $13^{d}.\ 00^{h}$.
Malabar	1 time	

It has not been possible to make much use of the British time-signals from the Greenwich Observatory, transmitted by Rugby Radio, owing to the very unsuitable times of transmission at 9.30 p.m. and 5.30 a.m. N.Z.M.T.

Seismology.—During the year 930 earthquakes were recorded on the seismographs. The total number of earthquake shocks felt in New Zealand was 678 : 93 of these were felt in the North Island and 624 in the South Island. In thirty-nine cases the same shock was felt in both islands. The abnormal number of shocks is due to the numerous after-shocks of the earthquake of 1929 June 17. In addition to the instrumental records of earthquakes, reports on all earthquakes felt are sent to the observatory from a large number of observers.

The outstanding seismic phenomenon of the year 1929 was the disastrous earthquake which visited the north-western portion of the South Island on June 17. This shock was distinctly felt over the whole of New Zealand, and resulted in the loss of seventeen lives, and serious damage to property in the Buller district, South Island. The intensity in this region was between 9 and 10 on the Rossi-Forel Scale.

Occultations.—With the assistance of members of the New Zealand Astronomical Society resident in different parts of the Dominion, arrangements have been made for the observation of occultations of stars by the moon, and the results of the observations have been sent to Dr. L. J. Comrie, *Nautical Almanac* Office, London.

Sunspots.—An enlarging camera for photographing sunspots is fitted for use with the Wellington City Council's 9-inch equatorial telescope. The camera is available for any particularly interesting groups of sunspots.

Numerous observations of the sun are made by members of the Solar Section of the New Zealand Astronomical Society, and the records obtained are available for use at the observatory. Arrangements have been made to send these observations to Zürich, where they will be used for international work in determining the " Wolf-Wolfer Relative Sunspot Numbers."

Spectrohelioscope.—A letter was received from Dr. Walter S. Adams, the Director of the Mount Wilson Observatory, in which he intimated that Dr. G. E. Hale, the designer of the spectrohelioscope, had offered to present one of these instruments to New Zealand. The instrument will be one of a number placed at different observatories around the world. The longitude of New Zealand is such as to make it a very valuable station, and it is hoped to obtain funds to install the instrument and keep it actively and regularly in use in order to assist in the international programme.

The largest refractors in use in New Zealand are the $9\frac{1}{2}$-inch visual refractor at Wanganui, and the 9-inch photo-visual refractor at Wellington.

Publications.—The following observatory publications have been issued during the year :—

Bulletin No. 76.—New Zealand Time-Service Arrangements.

Bulletin No. 77.—Report of the Dominion Astronomer and Seismologist for the year 1928.

E. 16.—Earthquake Report for 1928 January to March.

E. 17.—Earthquake Report for 1928 April to June.

E. 18.—Earthquake Report for 1928 July to September.

E. 19.—Earthquake Report for 1928 October to December.

As in past years, the observatory is again indebted to individuals and to institutions for valuable gifts of publications. Some of these are presented in exchange for the *Bulletins*.

Mr. A. F. Bennett's Observatory, Leiston, Suffolk.

Solar observations, direct and spectroscopic, have been continued as previously. A number of lunar occultations have been observed and the reports of them will be published in due course. The star cameras have been used for photographing various fields, including that of the new planet Pluto, on which some exposures were made when its discovery was first announced. Visual observations of variable stars, the planets and other objects, have been made with the 6-inch equatorial.

Early in the year the equipment was augmented by the installation of a precision regulator, beating seconds and adjusted to keep mean time. This clock has been regularly and carefully rated and its performance is remarkably good and consistent. It is already proving its value in cases where, as in occultations, precise determinations of time are essential.

On the whole, the seeing conditions have not been so good as in average years at this station.

Rev. T. E. Espin's Observatory, Wolsingham.

The search for new double stars in the selected zones has been continued during the year, and the results communicated to the Society.

Mr. F. J. Hargreaves' Observatory, Kingswood, Surrey.

Very bad observing conditions have been experienced throughout the year at this observatory, and the amount of observational work done has been very small. As an example, only one lunar occultation was timed during the whole year, although on another occasion (1930 February 8) the star, *k* Tauri, was not occulted, and this negative observation may have some value.

Visual observations of Jupiter were continued until 1930 April 29, but were much hampered by bad seeing and poor visibility. During February an exceptionally rapid current was detected in the latitude of the North North-Temperate Belt, the rotation period of a succession of dark spots in this region being $9^h\ 54^m\ 5^s$. Very poor conditions have prevailed so far during the present apparition of Jupiter, but a few experimental photographs of the planet have been obtained which show promise that considerable detail will be obtainable in ordinarily steady and transparent air.

The investigation of the effective wave-lengths of stars by means

of a grating, mentioned in the last report, was discontinued owing to instrumental difficulties, chief among which was the inaccuracy of the driving train of the equatorial. A new and much more accurate drive was constructed during the summer (see *M.N. Supp.*, 1930) and other minor difficulties overcome, but the weather conditions so far have been such as to prevent the resumption of the observations.

Mr. Newbegin's Observatory, Starween, Worthing, Sussex.

Observations for prominences were made on 119 days, yielding 1568 prominences with a mean daily frequency of 13·17, a result practically the same as for 1929. The northern hemisphere was slightly the more active, but it is to be noticed that the northern excess was during the first six months of the year, and thereafter the southern hemisphere predominated. The east and west limbs were almost equal, with a slight preference for the west, but there were fluctuations from month to month.

Metallic activity was observed on 91 occasions, on 47 of which it was on the east limb. The majority of the prominences were in Class 1, and very few were violently active. *Hα* displacements were recorded in 64 prominences, 39 being on the east limb : of these, 49 displacements were to the violet, 10 to the red, and 5 both ways simultaneously. It was noticed that a few of these prominences were a long way outside the spot zones, in some cases the latitude being as high as 70°.

Although some large prominences were seen during the year, on the whole their extent was much less than in 1929, and in spite of the fact that the mean daily frequency remains about the same the areas offer distinct evidence of the decline in prominence activity.

Sunspots.—151 observations of sunspots were made, the mean daily frequency being 3·13. The first two months of the year yielded a mean daily frequency of 5·26, then there was a sudden drop, and the decline since February has been gradual but persistent, with a small temporary revival in August, continuing during September. In August there was at least one day free of spots. The year has been remarkable for the fluctuations in activity, periods of almost complete quiescence being followed by active ones of considerable extent.

Spectroscopic observations with the high dispersion Littrow grating spectroscope of all the principal groups have been continued, and the results published quarterly in the *Journal of the B.A.A.*, **40** and **41**.

Nine groups were visible to the unaided eye.

Mr. B. M. Peek's Observatory, Solihull, Birmingham.

The polar axis of the equatorial which carries the 12¼-inch mirror has been successfully fitted with a roller bearing. In consequence the 19·2 in. focus Cooke astro-camera, kindly lent by Mr. Percy Morris, and the 19·5 in. Watson, have now been mounted with the telescope.

Photometric observations of Nova Persei 1901 have been continued, and the results will be communicated to the Society.

During the year eight occultations of stars by the moon were observed, and the reduction of these has been commenced. The results of the 1929 occultations were communicated to, and have been reduced by, the computing section of the B.A.A. The usual physical observations of the major planets have been continued, Jupiter and Mars having claimed most attention.

Rev. T. E. R. Phillips's Observatory, Headley, near Epsom, Surrey.

In the earlier part of the year illness of the observer greatly interfered with observational work, and during the later months the seeing conditions were extremely unfavourable. Cloud, mist, and fog were very prevalent, and on the occasions when the sky was clear the definition was almost always exceptionally poor.

Observations.—Observations were made when possible of Jupiter and Mars ; and Mr. F. J. Hargreaves obtained some photographs of the former with the 18-inch reflector in December. Following on the violent disturbances of recent years, Jupiter is now passing through a period of remarkable quiescence, the surface presenting less distinctive detail than at any time during the past thirty-five years.

Mr. P. M. Ryves was in England during a portion of the summer, and obtained a number of observations of variable stars.

Publications.—The Twenty-fifth Report of the Jupiter Section of the British Astronomical Association, dealing with the apparitions of 1925 and 1926, has been published. The light-curves of 35 long-period variables contained in the Appendix to the 8th and 9th Reports of the B.A.A. variable star section have been investigated and analysed harmonically. The results are given in *B.A.A. Journ.*, **41**, 123. A summary of double star measures made with the 8-inch refractor in 1928, '29, and '30 has been communicated to the Society.

Instruments.—Dr. R. L. Waterfield is now resident in Headley, and is setting up at the observatory a photographic equipment consisting of cameras mounted on an English equatorial. It is proposed to obtain photographs of the outer extensions of the larger nebulæ and other faint objects.

The usual meteorological records have been continued.

Dr. W. H. Steavenson's Observatory, West Norwood.

Very little work was done during 1930. Absence in South Africa left the 6-inch refractor idle during the first seven months of the year, and it was dismounted and transferred to other hands early in the autumn. On November 1 there was erected in its place an equatorial reflector of 20·5 inches aperture, made and presented by Mr. J. H.

Hindle. The mirror is of 96 inches focal length, and the instrument can be used either as a Newtonian or as a Cassegrain. The observing conditions during the last two months of the year were abnormally bad, and not much could be done with the new telescope. However, its optical performance proves to be excellent, and it is hoped to use it extensively for visual photometric work on faint variables and novæ. It shows stars somewhat fainter than the 16th magnitude.

The mounting is of the fork type, and the telescope is driven by an electric motor, working from the mains.

A small observatory of the Harvard pattern, with double sliding roof, has been erected over the instrument.

Mr. H. G. Tomkins's Observatory, Dedham, Essex.

Further progress with the work of this observatory has been made during the year.

The 24-inch Cassegrain has been in continual use, and the focussing arrangements reported last year have proved very satisfactory. The new aluminium camera has been completed and brought into use. It has been arranged with interchangeable backs and plate-holders, so as to take full, half-size, or quarter-size plates as desired. This has been done by providing separate backs which fit on to the body of the camera and automatically register correctly, so that the change can be made in a few minutes. As each back has its own separate plate-holders, no carriers are required, and accurate registration of the plates also is secured. For visual work, solid aluminium slides, with holes threaded in them to take the eyepieces, slip into the back of the camera in the same way as the plate-holders, and the change can be made from photographic to visual work or *vice versa* in about one minute, leaving the eyepiece practically in focus, and only requiring slight alteration. This has resulted in much saving of time. Provision has also been made for 6-inch × 6-inch colour filters a few inches in front of the plate, and they can be inserted or changed without otherwise affecting either the camera or plate in any way.

The subsidiary mirror and apparatus for watching the lunar image before exposure, which was mentioned last year, has been found to be cumbersome to work, and its frequent adjustment wastes much time. A 6-inch Cooke object-glass has therefore been obtained, kindly tested for me by Dr. Steavenson, and found excellent. This is now to be mounted in a light tube, and used as a subsidiary on the Cassegrain, and, it is hoped, will enable the best results to be obtained with more certainty from the mirror, and reduce further the element of chance in selecting the right moment for exposure, which to some extent exists at present.

The mirrors were re-silvered during the year, the 24-inch face up and the smaller mirrors face down. Brashear's formula was used as before, but the caustic potash, formerly a 10 per cent. solution, was reduced in strength, two-thirds of the amount of potash being used, in

the same quantity of water as before, for the two coats. This gave a good control over the sludge in silvering, and a very satisfactory film.

The year has been a disappointing one as regards frequency of clear skies, especially in the latter half, and only 35 plates have been secured against 45 in the previous year, making a total of 124 altogether available for investigation. Three more " flows " on the lunar surface were reported to the Society at the June meeting, as well as a peculiar appearance on one of the plates near the crater Manzinus. The portion of the moon's surface was suitably placed again for observation of this feature in 1929 December, but heavy rain effectually prevented it. It was, however, photographed on 1931 January 6. As regards the plates already obtained, nine of the bright ray systems and their surroundings have been examined in detail, in addition to the " flows" already referred to, and it is hoped that the work will shortly be sufficiently advanced to enable a report of the results to be made during the current year.

Notes on some Points connected with the Recent Progress of Astronomy.

Discovery of Minor Planets in 1930.

One hundred and sixty-two planets were discovered in 1930, as follows :—

Month and Designation.	Day of Month.	Magnitude.	Discoverer.
Jan.			
AA	4	14·5	MW
AB	4	14	R
AC	4	14	R
AD	7	13·3	R
AE	7	14	R
AF	7	13·3	GN
BA	20	14·0	R
BB	24	14	R
BC	24	14	R
BD	26	15	R
BE	26	14	R
BF	27	14	R
BG	27	16	MW
BH	27	13·8	R
BJ	27	14	R
Feb.			
CA	2	13·0	SB
DA	21	14	R
DB	21	14	R
DC	21	13·9	R
DE	22	14·5	MW
DF	22	15·5	MW
DG	22	15	MW
DH	22	15·5	MW
DJ	24	15·5	MW
DK	24	13·8	R
DL	24	13	MW
DM	24	14	R
DN	22	16	MW
DO	22	14·5	MW
DP	27	14	R
DQ	27	13·8	R
DR	27	14	R
DS	28	13·8	R
DT	28	15·5	MW
DU	24	13·2	GN
Mar.			
EA	1	14	R
EB	2	14	R
EC	3	14	R
ED	3	14	R
EE	3	15	R
EF	5	13·7	GN
FA	20	15·5	WB
FB	20	13·5	WB
FC	24	14	GN
FD	24	13·5	GN
FE	25	14	GN
FF	30	14	R
FG	30	14	R
FH	30	13·9	R
FJ	30	14	R
FK	30	14	R
FL	30	13·9	R
FM	18	13·9	O
Apr.			
GB	4	13·5	GN
GC	3	14	GN
HA	22	16·5	MW
HB	22	13·8	R
HC	25	13·7	R
HD	28	14	R
HE	28	14·0	R
HF	28	14	MW
HG	28	13·5	SB
HH	29	13·5	J
May			
JA	1	14	R
JB	1	14·0	R
KA	17	14	J
KB	17	14	J
KD	17	13·5	J
KE	25	13·3	J
June			
MA	27	12·5	P
MB	30	14·0	R
MC	30	15·0	R
ME	19	13·3	HW
July			
OA	18	13·0	GN
OB	22	13·5	GN
OC	24	13·6	ES
OD	28	13·4	GN
OE	28	13·6	GN
OF	26	12·6	V
Aug.			
PA	2	13·3	GN
PB	3	13·7	ES
QA	25	12·8	D
QB	26	11·8	A
QC	26	..	PS
QD	27	..	PS
QE	26	13·5	A
QF	28	..	D
QG	30	14·8	MW
QH	30	15·0	F
QJ	20	13·7	ES
QL	21	13·2	J
QM	21	13·6	J
QN	21	13	J
QO	24	13	J
QQ	26	13·6	A
QR	26	13·8	A
Sept.			
RA	2	..	D
RB	2	14	MW
RC	2	15	R
RD	2	14	R
SB	30	11·9	JS
SC	24	14	R
SD	28	12·9	R
SE	17	13·5	GN
SF	17	14·5	GN
SG	17	12·5	GN

Month and Designation.	Day of Month.	Magnitude.	Discoverer.
Sept.			
SH	20	13·3	GN
SJ	28	13·7	R
SK	20	13·5	GN
SL	20	13·8	GN
SM	20	13·6	GN
SN	20	14	GN
SO	21	13·2	ES
SP	21	13·5	ES
SQ	29	12·0	D
SR	19	13	KN
SS	26	12·7	KN
Oct.			
TA	3	12·0	A
TB	3	13·6	A
Oct.			
TC	14	14	R
UA	17	14·5	R
UB	17	14·5	R
UC	17	14·3	R
UD	17	13·8	R
UE	17	14·5	R
UF	17	13·2	GN
UG	18	14	GN
UH	18	14	GN
UJ	18	13·5	GN
UK	18	12·8	GN
UL	18	13·0	GN
UM	18	13·0	GN
UN	20	12·5	GN
UO	20	13·0	GN
Nov.			
VA	2	13·0	GN
VB	14	15	R
VC	14	14·5	R
VD	15	13·0	D
VE	15	13·0	D
VF	15	14·5	R
VG	15	14·8	R
VH	15	15·0	R
VJ	15	15·0	R
VK	1	16·2	GB
VL	1	16	GB
WA	24	13·1	LB
WB	26	13·0	D
WC	25	13·4	GN
WD	25	13	GN
Nov.			
WE	25	13·5	GN
WF	26	13	GN
WG	28	13·7	GN
WH	29	13·5	GN
Dec.			
XA	11	14	R
XB	11	14·5	R
XC	13	13·8	LB
YA	18	15	R
YB	18	14·5	R
YC	19	13	MW
YD	19	14·8	R
YE	20	15	MW
YF	23	15	R

The initials stand for: A = S. Arend, Uccle; WB = W. Baade, Bergedorf; SB = S. Beljawsky, Simeis; GB = G. van Biesbroeck, Yerkes; LB = L. Boyer, Algiers; D = E. Delporte, Uccle; F = M. Ferrero; J = C. Jackson, Johannesburg; KN = K. Nakamura, Kyoto; GN = G. Neujmin, Simeis; O = O. Oikawa, Tokyo; P = P. Parchomenko, Simeis; R = K. Reinmuth, Königstuhl; ES = E. Skvortzoff, Simeis; JS = J. Comas Sola, Barcelona; PS = P. Stroobant, Uccle; V = L. Volta, Turin; MW = M. Wolf, Königstuhl; HW = H. E. Wood, Johannesburg.

Additional planets, discovered in 1929, but not announced in time for last Annual Report: ND, RZ, RA_1, VH (all at Johannesburg), VJ at Königstuhl; XE at Tokyo; also *Astr. Nach.*, 5724, gives positions for many new images of planets (old and new) found on re-examining plates exposed at Königstuhl between 1900 and 1928. 1929 XE, numbered 1139, has an interesting orbit with n 1306″; it approaches close to the orbit of Mars at long. 40°, its perihelion distance being 1·449. An additional planet, 1915 u, has been found on Simeis plates. 1930 AF was detected on Turin plates of 1929 December 28, 29.

The following identities have been established: 38 = 1904 i, 491 = 1930 QK, 647 = 1930 SA, 661 = 1930 KC, 677 = 1906 UP, 847 = 1906 VJ = 1908 BT, 871 = 1930 DD, 912 = 1930 GA, 939 = 1930 QP, 981 = 1928 TG, 1003 = 1915 WZ, 1093 = Σ10, 1114 = 1906 WA, 1924 SL = 1930 HH, 1929 PB = 1929 PD, 1930 DK = 1927 QD, 1930 TA = 1926 AD, 1930 TA = 1913 SY.

An object named 1930 MD proved to be a variable star, not a planet.

The following identities are possible: 1906 UR with Σ42, 1930 SQ with 330. The last report mentioned that 1929 RK was suspected to be a Trojan. This is not the case, its period being 3·73 years.

The following planets have received permanent numbers: 1927 CO = 1929 QG = 1111, 1928 PE = 1112, 1928 XC = 1115, 1929 GD = 1116, 1927 KA = 1117, 1927 QD = 1930 DK = 1118, 1927 UB = 1119, 1928 RV = 1120, 1928 RZ = 1121, 1928 SB = 1924 TG = 1122, 1928 ST = 1123, 1928 TB = 1926 FC = 1124, 1928 UF = 1928 WC = 1125, 1929 AC = 1926 GD = 1126, 1929 AJ = 1127, 1929 EB = Σ100 = 1128, 1929 PH = 1905 PR = 1926 AE = 1129, 1929 RC = 1906 WH = 1130, 1929 RO = 1131, 1929 RB1 = 1132, 1929 RC1 = 1133, 1929 SA = 1134, 1929 TA = 1135, 1929 UA = 1136, 1929 WB = 1137, 1929 WF = 1138, 1929 XE = 1139, 1929 YC = 1140, 1930 AA = 1141, 1930 BC = 1907 XR = 1908 CY = 1142, 1930 BH = 1143, 1930 BJ = 1144, 1929 CC = 1145, 1929 JF = 1146, 1929 LF = 1147, 1929 NA = 1148, 1929 PF = 1149, 1929 RB = 1150, 1929 RK = 1151, 1924 SF = 1926 AK = 1930 AD = 1152.

The following planets have been named: 902 *Probitas*, 904 *Rockefellia*, 908 *Buda*, 913 *Otila*, 918 *Itha*, 920 *Rogeria*, 921 *Jovita*, 923 *Herluga*, 924 *Toni*, 926 *Imhilde*, 927 *Ratisbona*, 928 *Hildrun*, 929 *Algunde*, 933 *Susi*, 935 *Clivia*, 936 *Kunigunde*, 938 *Chlosinde*, 939 *Isberga*, 940 *Kordula*, 942 *Romilda*, 943 *Begonia*, 948 *Jucunda*, 956 *Elisa*, 957 *Camelia*, 958 *Asplinda*, 963 *Iduberga*, 968 *Petunia*, 970 *Primula*, 973 *Aralia*, 974 *Lioba*, 975 *Perseverantia*, 983 *Gunila*, 985 *Rosina*, 987 *Wallia*, 994 *Otthild*, 995 *Sternberga*, 996 *Hilaritas*, 997 *Priska*, 1068 *Nofretete*, 1073 *Gellivara*, 1102 *Pepita*, 1111 *Reinmuthia*, 1112 *Polonia*, 1122 *Neith*, 1124 *Stroobantia*, 1125 *China*, 1127 *Mimi*, 1128 *Astrid*, 1129 *Neujmina*, 1134 *Kepler*, 1136 *Mercedes*, 1143 *Odysseus*, 1145 *Robelmonte*, 1930 *UA Aeneas*, *UB Anchises*, 946 *Poesia*, 1003 *Lilofee*.

943, 957, 968, 970, 985 provide a celestial flower-bed; 902, 975, 996 were named by an admirer of their discoverer, the late Dr. Palisa, in commemoration of his sterling qualities. The names of 927, 1134 were given at the Kepler Commemoration; the masculine name of 1134 is justified by its small perihelion distance, 1·432. The names of 958, 1111, 1124, 1129 honour distinguished workers in minor planet astronomy. 1152 was the last of the 125 planets discovered by Dr. Palisa. He found it in 1924, but it remained for some years without a number, till it was identified by B. Asplind with planets observed in 1926 and 1930.

Three new Trojan planets were discovered during 1930; 1143 *Odysseus* is in longitude 60° greater than Jupiter, while UA and UB, discovered on a single plate, are in longitude 60° less; there are now five known Trojans on the side of greater longitude, four on the other. 1930 SH was thought to be a Trojan, but proved to be of *Hilda* type, with n 439″. Two other planets have interesting orbits; 1930 FB was moving north 23′ daily at discovery; it has i 27°, e 0·26, n 941″;

1930 SQ, which had already been photographed at Kwasan on September 19, has i 22°, e 0·30, perihelion distance 1·63, less than the aphelion distance of Mars; it is probably identical with 330 *Adalberta*, seen twice in 1892, but not since. The period would be 3·61 or 3·31 years, taking 11 or 12 revolutions between the perihelia of 1891 and 1931. If this identification is right, there are now only four lost planets in the first 400.

N. Comendantoff has published tables of Ceres in *Pulk. Observ. Bull.*, **12**, No. 2; they extend from 1801 to 2000. In *Astr. Nach.*, 5756, H. Rügemer studies the perturbations of the Trojans by Saturn, and by some other planets.

In *Astr. Nach.*, 5689, K. Boda publishes approximate Jupiter perturbations of 160 planets, and J. G. Behrens does so for 22 planets.

In *Astr. Nach.*, 5694, N. Mikhalsky publishes perturbations of 659 Nestor by Mercury, Venus, Earth, and Mars.

In *Astr. Nach.*, vol. 239, p. 313, P. E. de la Villemarqué gives absolute perturbations of 1139, the interesting planet discovered at Tokyo in December 1929 (see above). He gives perturbations of 113 in *Astr. Nach.*, 5760.

A. O. Leuschner and H. Thiele have completed their research survey of 1091 planets, and have formed tables from A.D. 1930 to 2020 of the Jupiter perturbations of the twelve J. C. Watson planets (*P.A.S.P.*, 1930 October).

This is the fortieth consecutive Minor Planet report contributed by the writer. His report of 1892 February began with the discovery of No. 303, and contained the sentence: "323 is interesting as being the first new asteroid discovered by photography."

A. C. D. C.

Report on Comets in 1930.

Three comets discovered in previous years continued to be visible in 1930. 1925 II. (Schwassmann-Wachmann (1)), discovered in 1927, was still under observation at the end of the year at Bergedorf and Yerkes, being fainter than magnitude 17. It will reach aphelion in two years, and hopes are entertained that it may be followed round its whole orbit, which lies entirely between the orbits of Jupiter and Saturn. 1927 IV. (Stearns) also continues to be observed at Bergedorf and Yerkes, its magnitude being fainter than 17. It is now outside the orbit of Saturn, and is farther from the sun than any comet has previously been observed. 1930 II. (Wilk) was mentioned in the last report, having been discovered on 1929 December 20. It was a very easy object in 1930 January, having a tail fully a degree in length; it was followed till nearly the end of January, after which it was too near the sun for observation; there are no records of any subsequent observations. The orbit does not differ much from a parabola.

Comet 1930 a = 1930 II. was discovered by Drs. Schwassmann and Wachmann at Bergedorf on February 18, and independently by Mr. L. Peltier at Delphos, Ohio, on February 20; it was of magnitude

$10\frac{1}{2}$, and was moving at the rapid rate of $-13\frac{1}{2}$ minutes in *R.A.* and $4\frac{1}{2}°$ north per day; it was then only some 20 million miles from the earth, and had passed perihelion in mid-January; it had an obvious nucleus in a coma some 4′ in diameter, which was extended towards the west; there was a tail 2′ in length in *P.A.* 185°, and a fainter one in *P.A.* 10°; this comet faded very rapidly; on March 3 Dr. G. Struve at Berlin noted that it was extremely faint, about magnitude 15. Professor van Biesbroeck followed it visually at Yerkes till March 5, when it had a nucleus of magnitude 15 surrounded by a faint coma 40″ in diameter; he obtained a photograph on March 19, when the magnitude was 16.

Comet 1930 *b* = 1930 IV. was found by M. Beyer at Grossborstel, Hamburg, on March 11, its magnitude being 10. Images were subsequently found by Dr. Prager on Ernostar plates taken at Berlin on January 23, February 18, March 2 and 3. The comet did not pass perihelion till April 18, its perihelion distance exceeding two units. A photograph by Professor van Biesbroeck on April 22 showed a fairly sharp nucleus surrounded by a round coma less than 1′ in diameter. On May 28 M. Plakidis at Athens gave the magnitude as 14, and the diameter of coma 90″. It was still under observation at Yerkes on November 18, when it was a small round nebulosity of magnitude 15. It reached north declination 57° in July, so it could be followed continuously at northern observatories. It does not seem to have had much tail, but a slight elongation of the coma away from the sun was noticed at Yerkes. C. Bower and Miss Moore found an elliptical orbit, with period 640 years, from the early observations; but a month later they substituted a parabolic orbit. There is material for an accurate deduction of the period, but this has not yet been made.

Comet 1930 *c* = 1930 III. was found by Mr. A. Wilk at Cracow on March 21; it was his third discovery, and followed his second one by only three months. It became visible to the naked eye at the end of March. Professor van Biesbroeck photographed a tail over $1\frac{3}{4}°$ in length, consisting of a bundle of divergent streamers; there was a round coma 3′ in diameter. The declination of the comet was 45° north in May, so it was conveniently placed for observation. The orbit showed some resemblance to that of de Vico's comet, 1846 IV.; the hypothesis of identity, however, proved untenable. Professor Banachiewicz found a period of 466 years. In May and June the coma expanded to some 10′ in diameter, the nucleus being very faint. Professor van Biesbroeck observed it visually up to the first week in July; it was then 3′ in diameter, but excessively faint.

Comet 1930 *d* = 1930 VI., found on May 2, was another discovery by Drs. Schwassmann and Wachmann at Bergedorf; it is the third comet of short period that they have found. There is a decided similarity between its orbit and that of comet Pons-Winnecke, suggesting a possible common origin. The new comet, like the other, made a close approach to the earth, its distance on June 2 being some five million miles. M. Baldet observed the comet at this time with the Meudon 33-inch refractor; he noted that the nucleus was very small, of

Ref. No.	Year and Number of Comet.	Name.	T.	ω.	Ω.	*i*.
				° ′ ″	° ′ ″	° ′ ″
506	1913 III	Neujmin (1)	Aug. 16·46112	346 14 9	347 53 49	14 50 10
554	1925	Wolf	Jan. 3·46444	177 28 31	269 17 44	23 46 32
578	1927 VI	Gale	June 14·57735	209 51 12	67 4 27	11 22 24
586	1929 II	Forbes	June 26·04625	259 28 40	25 29 26	4 38 12
588	1930 I	Schwassmann-Wachmann Peltier	Jan. 15·686	325 10 18	147 33 12	99 54 36
589	1930 II	Wilk	Jan. 22·3246	157 28 11	178 59 10	124 31 33
590	1930 III	Wilk	Mar. 28·800	46 56 42	90 16 0	67 7 18
591	1930 IV	Beyer	Apr. 18·790	29 56 18	116 27 9	71 49 51
..	1930 O	d'Arrest	P May 10·037	174 7 42	143 32 42	18 3 24
592	1930 V	Forbes	May 10·45304	320 59 36	278 17 22	97 5 55
593	1930 VI	Schwassmann-Wachmann	June 14·21981	192 19 24	76 45 12	17 17 54
..	1930 *g*	Nakamura	Aug. 21·37	40 19 0	231 26 0	8 7 0
..	1930 *f*	Tempel (2)	Oct. 5·73	186 35 19	120 21 7	12 46 32
..	1931	Neujmin (1)	P May 8·96	346 57 14	347 15 15	15 9 21

T is in G.M.T. to the end of the year 1924, in U.T. from that point.

The elements of Tempel (2) were obtained by applying approximate perturbations by Jupiter and Saturn to the elements obtained by H. M. Jeffers for the 1925 apparition. They still need small corrections to obtain perfect accord with the 1930 observations.

The elements of 1930 *g* are derived from an arc of two days, and are uncertain.

magnitude 14; assuming it to be a single solid body he deduced a diameter of $\frac{1}{4}$ mile; the nucleus passed within 1″ of a star of magnitude 11; the star was unchanged in magnitude and aspect, showing the transparency of the cometary matter, even in its densest region. The coma was 5′ long and 1′ wide, the latter corresponding to 1500 miles; it was extended from *P.A.* 40° to 220°; there was a gaseous nucleus $3\frac{1}{2}$″ long by $2\frac{1}{2}$″ wide; the stellar nucleus was $\frac{1}{2}$″ west of the centre of this. *Popular Astronomy* for June–July contains a photograph by Professor van Biesbroeck on May 24; the coma is shaped like the bulb of an incandescent electric lamp, some 8′ in its longer axis. There is a fainter fringe to this, and a very faint tail. In the issue for August–September he reproduced a pen-and-ink drawing, showing the comet's aspect on May 31. It resembles a dumb-bell, the nucleus corresponding to the central bar; there are elongated nebulous masses on each side of this; the eastern one being the larger. The space between these, on either side of the central bar, is filled in with faint nebulosity.

The comet crossed the equator on June 3, on which day it was picked up by Mr. Blathwayt at Johannesburg; he had not heard of the previous discovery. It was followed at Johannesburg by Mr. Wood till the end of August, but the latest published orbit does not include observations beyond June 2; the period given is $5\frac{1}{4}$ years. A careful watch was kept in Japan for meteors associated with this comet; the results are given in a paper by Professor Nakamura (*M.N.*, **91**, 204, 1930).

Ref. No.	log q.	Period in Years or Eccentricity e in Hyperbolic Orbits.	Equinox.	Computer.	Reference.
506	0·184296	17·75212	1913·0	G. van Biesbroeck	*A.J.*, 940.
554	0·385682	7·48817	1925·0	S. Kanda	*Tok. Bull.*, 39.
..	0·083856	11·02975	1927·0	Miss M. W. Makemson	*L.O.B.*, 426.
586	0·184195	6·38248	1929·0	B. H. Dawson	*A.J.*. 934.
588	0·03655	..	1930·0	J. P. Möller	*U.A.I. Circ.*, 251.
589	9·826491	20090	1930·0	F. E. Seagrave	*Pop. Ast.*, Apr.
590	9·68282	465·68	1930·0	T. Banachiewicz	*U.A.I. Circ.*, 290.
591	0·316300	1612	1930·0	C. H. and M. H. Smiley	*Obs. Mag.*
..	0·133202	6·6461	1930·0	..	*B.A.A.J.*, **40**, 175.
592	0·061810	..	1930·0	A. C. D. Crommelin	*U.A.I. Circ.*, 293.
593	0·004934	5·2668	1930·0	Miss Hayford and Anderson	*Harv. Card*, 135.
..	9·3070	..	1930·0	Y. Sibata	*Kwasan Bull.*, 183.
..	0·119890	5·16738	1930·0	A. C. D. Crommelin	*B.A.A.J.*, **41**, 46.
..	0·184567	17·68535	1931·0	G. van Biesbroeck	*A.J.*, 940.

Elements of Neujmin (1) for 1931, almost identical with those above, are given in the *B.A.A. Handbook* for 1931. T is there given as May 7·4.

It should have been stated in the last Report that comet 1929 II (Forbes) was observed by G. Adamopoulos at Athens on 16 days, extending from 1929 August 7 to September 9 (*Astr. Nach.*, **238**, 403).

Comet 1930 *e* = 1930 V. was found by Mr. A. F. I. Forbes at Cape Town on May 31 ; it was of magnitude 9, in south declination 33°, but moving northward ; it was picked up by Professor van Biesbroeck on June 21, and by Dr. G. Struve at Berlin a little later. Mr. Forbes's first two comets were of short period, but this one has an appreciably parabolic orbit. A tail 3′ in length was noted at Yerkes on June 21 ; on June 29 it was described at Berlin as a fairly round faint nebulous mass, with diameter 30″ to 40″. It was followed photographically at Yerkes till July 17, when the nucleus appeared diffuse in a coma 1′ in diameter. Total magnitude 15.

Comet 1930 *f* was the periodic comet Tempel (2), of which a search ephemeris was given in the *B.A.A. Handbook* for 1930. It was found by Mr. H. E. Wood at Johannesburg on August 26, and confirmed two days later. It was of magnitude 12 ; no nucleus was visible. Professor van Biesbroeck independently detected it on September 22. It was followed up till December, reaching magnitude 11. It is fortunate that it was found on this occasion, as the next two returns will be unfavourable, the comet being near conjunction with the sun at perihelion.

Comet 1930 *g* was found photographically by Professor K. Nakamura at Kyoto on November 13, its magnitude being 13·5. Photographic positions were also obtained on November 14 and 15 ; on November 16 Professor Nakamura observed it visually, noting that its image was fairly sharp and somewhat elongated. Mr. Sibata deduced a parabolic orbit from the positions of November 13, 14, 15. This was

telegraphed to Europe and America, together with an ephemeris. Professor van Biesbroeck noted, in *Pop. Ast.* for December, that he made careful search in the ephemeris place, both by eye and by camera, on November 20, without finding anything as bright as magnitude 16. It is difficult to imagine that the comet should have faded so rapidly ; there is, for the moment, no explanation of the discordance between his experience and that from Japan.

Two comets, Daniel 1909 IV. and d'Arrest, for which search ephemerides were given in the *B.A.A. Handbook* and *Journal*, were sought for unsuccessfully. The experience of 1923 indicated that the latter is subject to capricious changes of brightness. Mr. Cripps had carefully calculated the perturbations of the former, but its position was necessarily uncertain after so many revolutions.

Mr. N. T. Bobrovnikoff publishes a paper in *Pub. Ast. Soc. Pacific*, 1930 December, in which he discusses the spectrum of Halley's comet in 1910 and the outward motion of the tail matter. Numerous photographs are reproduced, showing peculiarities of structure. Evidence is found for the presence of repulsive forces "several hundred times gravitation."

Mr. C. T. Jacob has sent a manuscript with a graphic account of the appearance of the comet as seen from Adam's Bridge, India, in April 1910. The head appeared of about the moon's angular diameter ; the tail looked like a "great gash in the sky" or a "search-light beam divided by faint shadows." It was slightly curved.

A. C. D. C.

The Discovery of Pluto.

(*See also Address on the Award of the Jackson-Gwilt Medal*, p. 434.)

Ever since the discovery of Neptune attempts have been made to detect the presence of an exterior planet by examining the small residuals between theory and observation in the positions of the outer planets. Much more use has been made of Uranus than of Neptune, since it is difficult in the latter to separate discordances due to unknown perturbations from those due to errors in the assumed elements of Neptune. Professor W. H. Pickering, however, made some use of Neptune, also of Saturn.

All the computers recognised that when the disturbing planet is considerably further from the sun than the disturbed one, there are two possible positions for the former, about 180° apart, between which it is difficult to distinguish. In the following table the various predictions have all been reduced to the epoch and equinox of 1930·0, assuming circular motion unless a prediction of e was made. They are divided into three groups.

I. The Pluto group, in which the longitude is within 27° of that of Pluto.
II. The group in which the longitude is about 180° from Pluto.
III. Those outside both the above groups.

	Group I.						Group II.			Group III.			
	P. Lowell, 1915.	W. H. Pickering, 1909.	W. H. Pickering, 1919.	W. H. Pickering, 1928.	Gaillot, 1909.	Actual Elements of Pluto.	P. Lowell, 1915.	Gaillot, 1909.	Lau.	Todd, 1877.	Forbes, 1887.	Lau.	See, 1904.
Mean dist.	43·0	51·9	55·1	30·1	66	39·5	44·7	44	46·5	52·0	104·4	71·8	42·2
Period, years	282	373·5	409·1	164·8	536·1	248	299	292	317	375	1066	608	275
e	·202	..	·31	·195	..	·248	·195	..	..	..	..	..	..
Long. perihelion	204°·9	..	280°·1	252°·5	..	223°·4	20°·7	..	..	..	..	..	..
Date perihelion	1991·2	..	1720·0	1973·8	..	1989·8	1994·9	..	..	..	..	..	..
Ω	..	..	100°	180°	..	109°·4	..	..	..	104°	..	..	..
i	10°	..	15°	..	..	17°·1	..	..	..	1°·4	..	..	..
Long. 1930·0	102°·7	135°·1	102°·6	135°	128°·5	108°·5	279°·0	308°·4	308°·9	221°·6	191°	173°·1	233°
Magnitude	12 to 13	13·4	15	$\left\{\begin{matrix}12{\cdot}2\ v\\13{\cdot}5\ p\end{matrix}\right\}$	..	15	12 to 13	..	..	13	..	..	..
Mass. (Earth=1)	6·7	2	2	0·75	24	..	7·6	5	9	..	..	48	..

v, p denote visual and photographic magnitudes.

Forbes's position was obtained from cometary statistics, and evidently has nothing to do with Pluto. If there is any planet corresponding to it, it is a different one.

The other predictions were based on discussion of the departure of Uranus from its tabular longitude.

Gaillot and Lau expressed decided preference for the region of Group II., as compared with Group I. Lowell was fairly evenly balanced between them, but ended by a slight preference for Group I. Pickering adhered to Group I. throughout, claiming that Neptune definitely indicated this.

The honours must be divided between Lowell's (Group I.) orbit and Pickering's of 1919. Lowell's is superior as regards the period, and the date and longitude of perihelion; Pickering's as regards node, inclination, magnitude and mass. Pickering, in his 1928 prediction, took the period the same as Neptune's; this prediction is inferior to that of 1919, except in two points. Its value of the mass appears to be nearer the truth, and it predicts the unexpected fact that the orbit of Pluto penetrates that of Neptune.

Lowell based his work on Gaillot's revision of the orbit of Uranus, and applied several successive least-squares adjustments in order to find the elements of a perturbing planet that would make the sum of the squares of the residuals in longitude a minimum. He recognised that the residuals were too small to give a precise result, saying, "Analytics thought to promise the precision of a rifle and finds that it must rely upon the promiscuity of a shot-gun after all." Some astronomers have pronounced that Lowell's erroneous prediction of the mass (probably at least six times the true value) invalidated all his work. Others have thought that this wrong value of the mass could be explained by the fact that, at the last conjunction of Uranus with Pluto about 1850, Pluto was in aphelion, and its perturbations of Uranus small; so that Lowell's result depended to a considerable extent on the comparatively rough observations of the eighteenth century.

In the opinion of Professor H. N. Russell (*Scientific American*, 1930 December), "The orbit, now that we know it, is found to be so similar to that which Lowell predicted from his calculations 15 years ago, that it is quite incredible that the agreement can be due to accident." Similarly M. Benjamin Jekhowsky (*Journ. des Observateurs*, 1930 October) says: "Les résultats qui viennent d'être indiqués . . . montrent enfin une fois de plus, que la planète transneptunienne est bien celle qui a été prédite par Lowell." The writer of this report fully concurs with these views, which seem to be supported by the general similarity between the predictions of Lowell and those of Pickering, the latter having used quite different methods, which depended to a large extent on Neptune instead of Uranus. It is right, however, to add that these views are not universally held.

Pickering's method was a semi-graphical one. He first studied the general character of the perturbations in longitude produced by an external planet on an internal one, particularly near the times of conjunction. He drew graphs of the displacements produced, then he

plotted the residuals in longitude of the three outer planets, correcting them as well as he could for erroneous period, eccentricity and apse line ; then he sought for signs of the characteristic curves due to conjunction. He was thus led to conclude that Neptune was in conjunction with the unknown about the beginning of this century ; the conjunction in longitude actually took place in 1891, and the nearest approach (19 units) in 1895.

He deduced a conjunction of the unknown with Uranus in 1859 in his first solution, changing the date to 1841 in his third. The mean of the two is the right date, the conjunction having occurred towards the end of 1850 at a distance of 30 units.

These two fairly correct estimates appear to show that the method is capable of giving some clue to the place of an unknown planet. It is considerably shorter than the laborious analytical method.

The search for the planet has been going on at Flagstaff since 1905, having been continued since Lowell's death in 1917 ; but owing to his over-estimate of the brightness, the exposures given were inadequate to show it, till Dr. Lawrence Lowell presented a more powerful camera in 1929.

A series of plates were exposed by Mr. Humason at Mt. Wilson in 1919 December and 1920 January with a 10-inch Cooke triplet ; exposures of two hours were given, and stars down to magnitude 17 appear on the plates. The region explored covered the places predicted by Lowell, and by Pickering in the *Memoirs* of 1909 and 1919. The zone of critical examination of the plates was confined to the region within 2° of the ecliptic, and the four images of Pluto which were on them were not detected till the observations of 1930 and 1927 gave a clue to their positions. The planet was then in latitude 4° south, and its magnitude was 15 ; the erroneous value 19 for the magnitude in *U.A.I. Circular* 288 should be corrected.

The early observations in 1930 sufficed to indicate that Pluto was distant from the sun about 41 units and to determine its velocity normal to the line of sight ; that in the line of sight offered much greater difficulty, and most computers favoured outward motion. Professor Banachiewicz and Dr. Smiley produced a useful search ephemeris, assuming parabolic velocity with (1) outward motion, (2) inward motion ; the truth almost certainly lay between these hypotheses. With its aid M. Delporte found an image on an Uccle plate, exposed on 1927 January 27 ; this indicated that the motion was inward, and established the close resemblance of the orbit to that predicted by Lowell.

The detection of the Mt. Wilson (1919) images followed, leading to further improvement in the orbit : images have now been detected on plates taken in 1903 (found by P. J. Melotte on a Franklin-Adams plate),* 1914 (M. Wolf, Königstuhl), 1919 (Mt. Wilson), 1921 and 1927 (Yerkes), and the orbit has been independently determined by several computers, so that the elements are known within narrow limits.

* The identity of the 1903 image is doubtful.

Both Dr. Zagar in Italy and Dr. Nicholson and Mr. Mayall at Mt. Wilson indicated the necessity of introducing the perturbations of Pluto by the other planets (especially Neptune) in order to represent the observations. The following elements by Nicholson and Mayall, referred to the centre of gravity of the solar system, are the most reliable mean elements at present available:—

T	1989 November 6·98 U.T.	
ω	113° 52′ 50″·6	1930·0
Ω	109 21 43 ·7	
i	17 8 38 ·1	
a	39·45743	
e	0·2485200	
Period	247·6872 years	
n	14″·32530	
q	29 ·65147	
k	0 ·01721363.	

The perihelion of Pluto is in longitude 223° 15′, the aphelion of Neptune in 224° 2′; the radius vector of Neptune at that point is 30·31, two-thirds of a unit outside Pluto's orbit. The nearest approach of the two orbits is about $2\frac{1}{2}$ units at longitude 276°; but, as Professor H. N. Russell has pointed out in *Scientific American* for 1930 December, it is necessary to go several thousands of years forward or backward to find a conjunction of Pluto with Neptune at minimum distance; conjunctions occur at intervals of 495 years, that being three times Neptune's period and twice Pluto's. The commensurability is so close that successive conjunctions occur at almost the same points of the orbits. When close conjunctions do occur, they will come in a series 5 centuries apart: the resulting change in Pluto's orbit is likely to be marked, and even that in Neptune's orbit appreciable. There is a less close commensurability with Uranus, which goes round nearly three times in 248 years. There are thus two conjunction-regions nearly opposite to each other, which move slowly forward. The last two conjunctions were in 1710 (distance 17 units) and 1850 (distance 30 units); the next will be in 1966 (distance 15 units). Unfortunately, observations of Uranus near 1710 were scattered and not very exact, while in 1850 Pluto was near its aphelion and the perturbations small. The approach to Neptune in 1895 (distance 19 units) has been used by Nicholson and Mayall to obtain a first estimate of the mass of Pluto. The difficulty is that, as Neptune has only been observed in a continuous manner over half its orbit, the maximum perturbation occurring near the middle of this period, the determination of Neptune's eccentricity is difficult to disentangle from that of Pluto's mass. Nicholson and Mayall find the value 1·08 × Earth for the mass, using Lalande's position of 1795, and 0·72 × Earth, omitting Lalande.

For comparison with these, an estimate is given in which it is assumed that the visual magnitude in 1930 March was 14·7, that the

albedo is the same as that of Mercury, and that the density is the same as that of the Earth. (The *Lowell Circular* of 1930 March 13 stated that the colour is yellowish, so the visual magnitude has been taken slightly brighter than the photographic one.) Using the formula given on p. 784 of *Naut. Alm.* for 1931, the magnitude of Mercury at unit distance from Sun and Earth and $i = 0$, is 0·0. At distance 41·3 from Sun, 40·8 from Earth, it would be 16·1, or 1·4 mag. fainter than Pluto. This gives a diameter 1·9 of Mercury's, or 0·72 of the Earth's, and a mass 0·38 of the Earth's. A greater mass would involve either a lower albedo than that of Mercury or a greater density than that of the Earth, neither of which seems probable.

Nicholson and Mayall give the following table of perturbations of Neptune by Pluto, on the assumption of a mass equal to the Earth's :—

Year.	Long.	Lat.	Year.	Long.	Lat.	Year.	Long.	Lat.
	″	″		″	″		″	″
1796	−·82	−·02	1844	+·08	−·07	1892	+ ·08	+ ·04
1800	−·69	+·09	1848	+·08	−·07	1896	+ ·05	+ ·04
1804	−·57	+·16	1852	+·06	−·06	1900	− ·02	+ ·01
1808	−·45	+·19	1856	+·04	−·04	1904	− ·15	− ·08
1812	−·34	+·18	1860	+·02	−·01	1908	− ·33	− ·20
1816	−·24	+·16	1864	+·01	·00	1912	− ·58	− ·35
1820	−·14	+·11	1868	·00	·00	1916	− ·90	− ·54
1824	−·07	+·06	1872	·00	·00	1920	−1·23	− ·77
1828	−·01	+·01	1876	+·01	·00	1924	−1·57	− ·96
1832	+·04	−·04	1880	+·03	·00	1928	−1·93	−1·09
1836	+·06	−·06	1884	+·05	+·01			
1840	+·08	−·07	1888	+·07	+·03			

A better value of the mass will be obtainable from the recent conjunction with Neptune, when a sufficiently long interval has passed to enable a new determination to be made of the eccentricity and apse of Neptune's orbit ; till then it is difficult to separate the perturbations from the errors in the assumed orbit.

Attempts will also be made to obtain the mass from the conjunction with Uranus in 1850 : inspection of the residuals from Gaillot's theory, as tabulated by Lowell on p. 32 of his 1915 memoir, do not suggest that a very trustworthy result can be obtained from them. The much closer approach in 1966 should give something of value.

The name Pluto was suggested by Miss Venetia Burney, great niece of Mr. H. G. Madan, of Eton, who suggested the names Phobos and Deimos for the satellites of Mars. The present suggestion was telegraphed by Professor Turner to Professor Slipher, who noted that he was guided by it in making his selection. The symbol PL has been adopted, which in addition to giving the first letters of Pluto, recalls the initials of Professor Percival Lowell.

A. C. D. C.

Solar Activity in 1930.

Sunspots.—The sunspot activity showed a large decrease as compared with that of 1929, and it is also evident from the occurrence of other solar phenomena that the declining phase of the eleven-year frequency cycle has been definitely entered upon. The average daily number of spots was about 7/10 that of the preceding year, whereas the average daily area was only 4/10. There was an absence of very large groups, the largest being that with central meridian passage on October 11, in latitude 7° N., and of maximum area about 1300 millionths of the sun's hemisphere. Besides this group of spots, there were some half-dozen other groups of maximum area 400 or 500 millionths of the sun's hemisphere. These spots when near the centre of the disc were usually just visible to the naked eye. Their times of central meridian passage and latitudes are as follows :—

Jan. 12·4	6° N.	Apr. 7·5	13° N.
Jan. 18·3	14° N.	Oct. 11·0	7° N.
Mar. 7·0	17° S.	Oct. 28·5	6° S.
Apr. 2·0	5° S.		

Considerable activity, seen in Hα light, took place in the immediate vicinity of the following groups of spots, including two in the above list. The time of central meridian passage of the spots is given, together with the date (in brackets) on which special activity was observed :—

(1) May 7·3 (May 5).
(2) Aug. 12·2 (Aug. 12).
(3) Aug. 24·9 (Aug. 20).
(4) Sept. 11·3 (Sept. 15).
(5) Oct. 11·0 (Oct. 6).
(6) Oct. 28·5 (Oct. 28, 29, 31).
(7) Nov. 24·7 (Nov. 25).

Each of the above groups was associated with the transitory appearance of brilliant hydrogen flocculi, Nos. 2 and 7 being notable examples. Spots Nos. 1, 2, 5, and 7 were associated with short-lived, rapidly moving dark hydrogen markings. Measures made with the spectrohelioscope gave the following velocities in km./sec., + denoting inward velocities to the sun and − outward velocities :—

(1) + 53 on May 5 ; (2) − 33 to + 115 on August 12 ; (5) + 100 to − 170 on October 6 ; (7) − 450 on November 25.

The details of the phenomena observed on August 12 and November 25 are given in *M.N.*, **90**, 820 and **91**, 239, 1930.

It may be remarked that, although the Sun's general activity showed a marked decline during 1930, the period was one of frequent terrestrial magnetic disturbance.

H. W. N.

The Prominences, 1930.—The outstanding feature of the data for 1930 is the progressive decline in every kind of prominence activity in accordance with the normal course of the sunspot cycle.

The mean daily areas of calcium prominences in square minutes of arc as derived from Kodaikánal photographs are as follows :—

	North.	South.	Total.
1930 January to June . .	3·13	2·16	5·29
July to December . .	1·36	1·96	3·32

The mean daily numbers were 12·3 and 12·9 for the first and second half-years respectively. The decrease on the year 1929 is 14 per cent. for areas and 13 per cent. for numbers. The distribution of prominence areas in latitude shows in the first half of the year an unusual activity in the northern hemisphere from 30° to 55°.

Prominences exhibiting metallic lines numbered 38 as against 52 in the year 1929. While in general they were not noticed beyond latitude 30°·5, one faint prominence of this type was observed at 45° on the N.W. limb during the second half-year. Displacements of the hydrogen line in the chromosphere and prominences observed during the year numbered 276 as against 598 in the previous year. Of the displacements 142 were towards the red, 122 towards the violet, and 12 both ways simultaneously. Bright reversals of the *Hα* line in the neighbourhood of sunspots numbered 450, while those observed in the previous year were 813. Displacements of the *Hα* line on the disc totalled 55 as against 172 in 1929. Of these displacements 39 were towards the red, 7 towards the violet, and 9 both ways simultaneously. D3 was observed as a dark line in 435 cases, as against 790 during 1929.

The mean daily areas of prominences projected on the disc as absorption markings in hydrogen light was 3443 millionths of the sun's visible hemisphere, representing a decrease of 19 per cent. on the year 1929.

The mean daily areas of hydrogen prominences in square minutes are as follows :—

	North.	South.	Total.
1930 January to June . .	1·22	1·00	2·22
July to December . .	0·48	0·66	1·14

These areas are only 42 per cent. of calcium areas in the first half-year, and 34 per cent. in the second. The curve of distribution of *Hα* prominences in latitude is intermediate between those of calcium prominences and of absorption markings. T. R.

Solar Research in 1930.

Reversing Layer.—Babcock gives an account (*Photographic Journal*, March 1930) of the solar spectrum over the range 9867–11,634 A. An exposure of about 6 hours in the first order of a six-inch grating gave 350 lines, including two lines of phosphorus (predicted by Dhaval) and probably a strong multiplet of carbon. Miss Moore announces (*P.A.S.P.*, **42**, 346) the identification of the strongest low-level lines of the ionized atom of lutecium in the solar spectrum. Babcock has examined (*P.A.S.P.*, **42**, 209) the distribution of lines of different

intensity in the revised Rowland Table for different wave-lengths. On the whole the number of lines increases with decreasing intensity and with decreasing wave-length, the latter variation being more marked in the Sun than in general laboratory results. On a scale of frequencies both the Sun and the laboratory give maximum numbers in the blue-green region. Minnaert and Mulders (*Zeit. f. Astroph.*, **1,** 192) have examined how much energy is absorbed in the Fraunhofer lines in the region 5150–5270 A. They find that the true intensity is higher for a given Rowland figure in the green than in the blue, and that approximately the intensity varies as $\sqrt{N}$, where N= the number of resonators involved in producing the line. Deviations from this law are real, weaker multiplet lines coming out relatively more intense than the stronger lines. Woolley (*Ap. J.*, **72,** 256) obtains this same result from some multiplets of titanium. These results throw doubt on the calibration by Adams and Russell of the Rowland scale, or alternatively on Unsöld's theory of the method of formation of absorption lines. Brück (*Zeit. f. Astroph.*, **1,** 58) examines the variations in structure of the Fraunhofer lines during a partial eclipse, and as they are of the same character as under ordinary conditions he concludes that the source of the disturbances lies in the Sun's atmosphere and not in the Earth's.

St. John (*Ap. J.*, **70,** 312) claims that the red shift is consistent for lines of the same multiplet, being greater for stronger multiplets. He also states that the excitation potential fixes the height of the effective absorbing layer in the Sun, the higher potentials corresponding to lower layers. Burns (*J.O.S.A.*, **20,** 212) finds the multiplet evidence conflicting and not consistent with St. John's explanation of the intensity term as due to convection currents. The intensity term comes out the same for different parts of the disc. Freundlich, Brunn, and Brück (*Zeit. f. Astroph.*, **1,** 43) in examining the limb effect for a sharp iron multiplet, get results which fail to agree with St. John's convection currents. Abetti and Novakova (*Oss. e Mem. del R. Oss. Astrof. di Arcetri*, No. 46) have examined the limb effect for a number of metallic lines near Hα and also fail to agree with St. John's solution.

Chromosphere and Prominences.—Mitchell (*Ap. J.*, **71,** 1 ; **72,** 146) gives a very complete new study of the fine chromospheric spectra secured by him at the eclipses of 1905 and 1925 (and, for the extreme ultra-violet, of Davidson's 1926 spectrum). He has revised the identifications in close co-operation with the recent work at Mt. Wilson. He finds that the higher lines reached the same level at both eclipses but that the lines of medium level reached lesser heights in 1905 (sunspot maximum) than in 1925 (nearer minimum). The coronal lines were also stronger at the latter eclipse. Mitchell gives some valuable statistical results. Among these we may mention that the lines of least excitation potential reached the greatest heights and were the most intense. Again, lines of intensity $n+2$ in the red reached the same height as lines of intensity n in the violet. The number of atoms involved in producing a line is the determining factor in this

as also in the relative behaviour of lines of the same excitation potential in the red and the violet. Mitchell does not agree with St. John that Sun *minus* arc is constant for all lines of the same multiplet, the stronger and weaker lines giving values with opposite signs.

Woltjer (*B.A.N.*, 182) suggests that the asymmetry of the K line found by Minnaert is due to the outward motion of Ca^+ atoms, the Ca^+ chromosphere being terminated by a second ionization at a height at which the outward velocities reach 550 km./sec. This height he calculates at 14,000 km. To Unsöld's criticism (*Obs.*, **53,** 148) that this view is inconsistent with the slow inward motion found by St. John for H_3 and K_3 Woltjer replies (*Obs.*, **53,** 211).

D'Azambuja (*Ann. de l'Obs. de Paris—Meudon*, **8**) gives a very interesting discussion of spectroheliograms obtained in different lines in the reversing layer, lines of *Fe*, *Ca*, *Na*, Sr^+, and Ca^+. He finds that the type of picture obtained depends mainly on the strength of the wings of the line used. For the centres of lines with strong wings there is close agreement with K; at the border of the centre, especially on the violet side, strongly marked granulation is shown, as in $H\alpha_2$. As we pass further into the wings bright faculæ reappear, strengthen, and fade away. On the red borders of narrow lines, dark areas coincide with the bright faculæ of H and K. A first attempt to compare granulation for different lines showed good agreement between *Fe* and *Ca*. Interesting spectroheliograms with the infra-red multiplet of Ca^+ were also obtained. Da Costa Lobo (*Anais do Obs. Ast. de Coimbra*, **1**) publishes an account of his spectroheliographic installation and, for the early part of 1929, daily spectroheliograms (disc and limb). Hale (*Ap. J.*, **70,** 265; **71,** 73) gives an interesting account of the spectrohelioscope, its history, its adjustments, and the method of observations. He gives many illustrations of results and shows how powerful an instrument the spectrohelioscope can be for studying local variations of motion. Accounts of eruptions observed with this instrument at Greenwich are given by Newton (*Nature*, **126,** 969; *M.N.*, **90,** 820; *Obs.*, **53,** 242). Other remarkable eruptions on the Sun are noticed by Roumens (*l'Astronomie*, **44,** 21) and Sellers (*Jour. B.A.A.*, **40,** 305). Evershed (*M.N.*, **90,** 762) examines the wave-length of $H\epsilon$ in prominences and finds it shifted to the red by the same amount as H. At the centre of the disc the hydrogen lines show a shift increasing with wave-length, suggesting a descending motion in the chromosphere. Perepelkin (*C.R. de l'Acad. des Sciences de l'U.R.S.S.*, 1930, p. 37; *Zeit. f. Astroph.*, **1,** 326) examines the rotational velocities of prominence matter at the summits and bases of prominence and finds that there are systematic differences in good accord with the theory of Pike and Milne. Chidambara Iyer (*M.N.*, **90,** 496) shows that the bases of prominences vary six times as much as do the heights, the spread of prominence matter tangential to the limb being much greater than movement of ejection. Eigenson (*A.N.*, **240,** 49) from a statistical study of prominences deduces from various correlation factors that the base is probably the chief form factor. A slight correlation is shown between form and heliographic latitude.

Corona.—v. d. Pahlen and Kohlschütter (*Veröff d. Univ. Sternw. zu Bonn*, No. 24) have examined Bredichin's and Störmer's theories of the formation of coronal rays. They apply the two theories to the corona of 1923 September 10, and find that Bredichin's theory of a solar repulsion fails to give the observed curves in the corona, but that Störmer's magnetic theory modified to admit of initial non-radial velocities would give possible trajectories for coronal particles. The very small solar magnetic field indicated is a difficulty in the theory. Another magnetic theory of the corona is outlined by Hulburt (*Phys. Rev.*, **35,** 1379). With a magnetic field normal to the radiation pressure in low latitudes, ions accumulate sufficiently to break the field down, and we get an outpouring of charged particles in a structureless formation. The plumes in the polar regions come from the parallel directions there of the lines of magnetic force and the pressure of radiation. Bergstrand (*Arkiv f. Mat. Ast. och Fys. k. Svensk. Akad.*, **22** A, 1) resolves the corona into equatorial jets superposed on a polar corona. An examination of the ellipticity of coronal isophotes shows that from sunspot maximum to minimum the polar corona is only 0·3 to 0·4 times that of the equatorial corona, but that after minimum it increases to a strength of 0·8 times that of the equatorial corona; this accompanies increased development of prominences in the high latitude zones. Taffara (*Publ. dell Oss. Ast. di Bologna*) confirms Horn d'Arturo's view that the differences in the coronal photographs secured in Africa and Sumatra in 1926 are to be ascribed in large part, if not in whole, to changes in the corona itself during an interval of 2·5 hours.

Rosenthal (*Zeit. f. Astroph.*, **1,** 115) suggests that the spectrum of the corona may be due to helium, with its inner electron at the 2*s* level. He gets reasonably good comparisons with theoretical intensities and frequency intervals, but the theory must await experimental verification. Anderson (*Zeit. f. Astroph.*, **1,** 336) does not accept Rosenthal's view that the vanishing of the Fraunhofer lines in the inner corona is due to repeated scattering: he suggests for the bright-line spectrum an application of Gurney's theory for the chromospheric lines. Minnaert (*Zeit. f. Astroph.*, **1,** 209) suggests that the scattering material in the corona is mainly to be found in bound electrons, the bright lines coming from recombinations. He objects to the suggestion of Mecke and Wildt (*Zeit. f. Phys.*, **59,** 501) that the coronal lines are to be explained as a Raman spectrum from sources in the extreme ultra-violet. Minnaert puts the temperature of the corona at 3000°–4000°. Freundlich (*Naturwissenschaften*, **15,** 323) reports the discovery by Grotrian of a new coronal line at 6704 A on a spectrogram secured at Takengon, 1929 May 9.

Lyot's important study of the corona outside eclipse is dealt with in a separate note. Special eclipse studies of the corona have been published by the following: (1) Pannekoek and Doorn (*Verh. d. k. Akad. van Wet. te Amsterdam*, **14,** No. 2) find the total light of the corona on 1927 June 29 as a little stronger than 0·5 that of the full moon and its distribution in wave-length closely in agreement with that of the Sun. They get the ratios of the absolute intensities

of the three coronal rings to be as follows : 6374 : 5303 : 3987=12·0 : 6·8 : 3·19 ; (2) Fessenkoff (*Publ. de l'Inst. Astroph. de Russie*, **4**) gives the coronal light as 0·4 times that of full moon for the same eclipse, while Michailov gets for the distribution of the light in the corona, $I \propto (\rho - 0{\cdot}7)^{-3}$, where ρ is the distance from the Sun's centre. Isophotes show ellipticity gradually increasing with distance from the limb ; (3) Mörikofen and Lindholm (*Archives des Sciences Phys. et Nat. Genève*, **11**) use a Michelson bi-metallic actinometer for the total radiation and the infra-red, and photo-electric cells for the blue-violet and ultra-violet ; (4) Danjon (*l'Astronomie*, **44,** 193) obtains from the eclipse of 1929 May 9 a mean value for the ratio (corona : full moon) of 0·41 in the range green to violet ; (5) Stetson (*Pop. Ast.*, **35,** 95) obtains for this eclipse a total illumination of 0·15 of a foot-candle, a result slightly in excess of the value found by him in Sumatra ; (6) R. L. Waterfield (*M.N.*, **90**, 605 ; *Pop. Ast.*, **387**, 479) obtains the same contour for isophotes in visual and infra-red light, but a much more rapid intensity gradient for the infra-red. None of the above results was unaffected by cloud.

Wright and Curtis have published a full account (*Sproul Obs. Pub.*, No. 11) of the unsuccessful attempts made at 4 eclipses (1923, 1925, 1926, 1929) to determine the rotation of the corona, by the method applied to the Orion nebula by Buisson, Fabry, and Bourget. They give full instrumental details and suggestions as to the most hopeful method of further attack.

Eclipses.—Additional eclipse reports have been published as follows : (*a*) *1927 June 29.*—Pannekoek and Doorn (*loc. cit.*) have carried out a photometric study of the chromosphere and prominences. Using the Schrödinger-Pauli formula for the hydrogen lines Hα to Hγ they derive a temperature of over 6000° for a prominence 23,000 km. high, with a partial pressure of $1{\cdot}2 \times 10^{-7}$ atmos. for hydrogen and of 10^{-19} atmos. for ionised calcium. In the low chromosphere a pressure of 10^{-4} atmos. is indicated. (*b*) *1929 May 9.*—Freundlich (*loc. cit.*) gives an account of the Potsdam expedition to Takengon, Sumatra, and of the successful plates taken to study the Einstein effect. Ferrié (*l'Astronomie*, **44**, 110) reports that at Poulo Condore wireless echoes entirely disappeared during the eclipse, and he suggests that this implies that they originate in the Kennelly-Heaviside layer. (*c*) *1930 April 28.*—Moore gives an account of the Crocker expedition from Lick (*P.A.S.P.*, **42,** 131, 182) ; the green coronal line can be traced on spectrograms to a height of 23,000 km., Hα to 11,000 km., and Hβ to 14,000 km. It should be possible to get the absolute intensity of the green coronal line from the plates. Maxima in the green coronal ring fall near the bases of prominences. S. B. Nicholson (*P.A.S.P.*, **42**, 152) secured Ca^{+} chromospheric rings at 8542, 8662. A moving film shows rapid changes in the Baily beads as the Moon passed through the central phase. Brackett (*P.A.S.P.*, **42,** 149 ; *Pop. Ast.*, **38,** 594) gives an account of a series of time records of photometer readings across the eclipse track and of aeroplane shadow photographs with

time-signals recorded on the films. (*d*) *1930 October 21-22.*—A preliminary notice has been given (*Daily Science News Bull.*, October 24) of the success of Mitchell's party from the Naval Observatory and of Adams's party from New Zealand. The corona was of intermediate type: coronal disturbances were associated with prominences. (*e*) *1932 August 31.*—Slocum (*Pop. Ast.*, **38,** 211, 409) has issued a report on the meteorological observations made for five years along the belt of totality from Hudson's Bay to the Atlantic. The result may be summed up as a 50 per cent. chance of good weather. Other papers on eclipses that may be mentioned are Davidson's account (*Obs.*, **53,** 252) of the value of diffraction gratings in eclipse work; Miss Lewis's study (*Pop. Ast.*, **38,** 325) of the maximum possible duration of a total solar eclipse, which for many hundreds of years cannot exceed $7^m31^s{\cdot}1$; Brouwer's method of making corrections to the central line of a solar eclipse, for small corrections to the co-ordinates of the Sun and Moon (*A.S.T.*, **40,** 27). Shistovsky (*Publ. de l'Inst. Astroph. de Russie*, **4**) claims that with the use of a cinema camera the flash spectrum can give the second and third contacts correct to nearly 0·1 sec.

Sunspots.—Perrakis (*Journal de Physique*, vii. **1,** 126) has observed D_3 in absorption in the spectra of spots and neighbouring faculæ, occasionally in other faculæ unaccompanied by spots. Piccardi (*Oss. e Mem. del R. Oss. Ast. di Arcetri*, **46**) has identified the secondary hydrogen spectrum in sunspots, the stronger lines of the Fulcher bands due to H_2. The presence of these lines is in accordance with physical considerations. Richardson (*P.A.S.P.*, **42,** 121) examines the evidence for the region 4500–5500 A, finds it to be fairly good but suggests that further investigation is desirable. Pettit and S. B. Nicholson (*Ap. J.*, **71,** 153) with a thermocouple and monochromator in the focal plane of the 150-foot tower telescope have obtained the result that the ratio of the intensity of spot to photosphere varies linearly from 0·21 at $\lambda=0{\cdot}3\ \mu$ to 0·80 at $\lambda=1{\cdot}7\ \mu$, and they derive a temperature of 4800° for the spot. The water-cell temperature comes out at 4720°. Petrie (*M.N.*, **90,** 480) has developed the theory of a sunspot, in which the cooling is caused by adiabatic expansion, and gets depths for the spots of about 100 km. Milne (*M.N.*, **90,** 487) takes account also of radiation-pressure and obtains for the rate of outflow of gases at the upper levels of sunspots, figures in good accord with the Evershed effect. Brunner (*Ast. Mitt. Zürich*) examines the complete Zürich material and confirms Joy's results on the inclination of the axis of a spot group to the equator. The westward or preceding spot is nearer the equator, and the slope increases with latitude but diminishes with the development of the group, partly on account of the forward movement of the spot in lower latitude. The effect is most pronounced for a group of small spots.

Periodicity.—Luby (*A.J.*, **40,** 27) works out a theory of spots as due to precessional disturbances in the Sun caused by the planets—not conical motions of the Sun's axis but varying strains in the body

resulting in fluid motions. He rejects the early periods and makes the cycle $11^{y}\cdot86$. Goschl (*Ast. Nach.*, **239,** 287) compares his forecast, based on a theory of planetary disturbances (published in *Ast. Nach.*, **234**), with the actual sunspot frequency in 1929. The results are not very convincing. Alter (*B.A.A. Jour.*, **40,** 99) ascribes sunspot periodicity to tidal influence, especially to the joint action of two planets. The results are analysed in terms of the synodic periods of the planets. O'Connor and De Lury (*Pop. Ast.*, **38,** 31) find from tree-growths a period of 11·5 years for sunspots, with a difference of 22 per cent. between growths at maximum and minimum for spruces and of 50 per cent. for a butter-nut tree. A pre-glacial spruce, thousands of years old, shows evidence of the same sunspot cycle with 18 per cent. difference of growth. Brunner (*loc. cit.*) puts the last sunspot maximum at 1928·4, and notes that it has several secondary maxima, repeated at intervals of 15, 16, 17 months. In this feature it resembles the maxima of 1829·9, 1894·1, 1906·4. Peters and Wagman (*Pop. Ast.*, **38,** 7, 88) also refer to the complex nature of the recent maximum and give an account of the photoheliograph in use at the Naval Observatory, Washington, for the last 30 years. Taffara (*Memorie d. Soc. Astron. Ital.*, **4,** 395, 1929), from a study of the variation in solar activity from 1877 to 1928, obtains a period of $11^{y}\cdot041 \pm 1^{y}\cdot17$—the interval from minimum to maximum being $4^{y}\cdot313$. Caldo (*Pub. del Oss. Ast. di Palermo, Mem.*, No. 55) has measured the diameter of the Sun during the years 1900–11, 1925–29, and found systematic variations, not connected with the solar period. The work is to be perfected and continued.

Solar Rotation.—Abetti and Novakova (*loc. cit.*) find that the rate of rotation for $H\alpha_3$ agrees closely with the mean of a number of results for the reversing layer both at the equator and in high latitudes. The angular velocity of rotation is greater for $H\alpha_3$ than for the mean of $H\alpha_{2r}$ and $H\alpha_{2v}$. The value for $H\alpha_2$ is the lowest yet recorded, $9^{\circ}\cdot1$ (or $39^{d}\cdot5$) in high latitude and $13^{\circ}\cdot9$ (or $26^{d}\cdot0$) at the equator. Westlands, O'Connor, and De Lury (*Pop. Ast.*, **38,** 99) working in the region of 5600 A (in 1914 May, June) find for the equatorial velocity of solar rotation, 1·90 km./sec. as against 1·95 km./sec., the average for 1909–1917. The later measures show a greater excess of values for the stronger lines over the weaker lines on the plates which yield the lower values for the velocity of rotation. Ross Gunn (*Phys. Rev.*, **35,** 635; **36,** 1251) explains the equatorial acceleration as due to a superimposed drift of solar atmosphere owing to the sweeping along of ions executing long free paths in crossed electric and magnetic fields, and suggests that variations of the Sun's rotation with solar activity might be due to a change in the flow of electrons from the Sun's surface, which would accompany variations in the Sun's radiation, in the ionization of the upper layers, their permeability, the magnetic field, and ultimately in the velocity of the atmospheric drift.

Solar Radiation.—Abbot (*Pop. Ast.*, **38,** 593) from a study of the Montezuma observations of the variation of solar radiation, finds

correlations with mean temperatures which differ at the same place at different seasons, and differ with different places. He suggests that the effect is not a direct one but one involving some mechanism of atmospheric circulation. Clayton (*Smithsonian Misc. Coll.*, **82,** No. 7) finds pressure contrasts increased and atmospheric circulation stimulated by increased solar activity. Pressures fall in equatorial belts and polar regions. Hanzlik (*Nat.*, **126,** 312) finds increased pressure over the Indian monsoon area with increase of spot activity, with possibly a long strip in the Pacific as a negative area. Other pieces of radiometric work to be mentioned include a study by Wiertz of observations made by the Kiel eclipse expedition to Gällivare in the summer of 1927 (*Ast. Nach.*, **239,** 177), an account of some observations with a new ice pyrheliometer by Vološin (*Bull. Inst. de l'Acad. des Sciences de Bohème*) and an actinometric bibliography by the same writer published under the auspices of the French Meteorological Office.

Structure of Solar Atmosphere.—Ambarzumian in a quantitative spectral analysis of the Sun's atmosphere (*Zeit. f. Phys.*, **60,** 255) discusses the discrepancies in the number of hydrogen atoms suggested by the contours of Hα and Hδ. He suggests that the boundary between the upper layer of monochromatic emission and the lower layer of continuous emission must be different for different lines. Kremer (*Proc. Konink. Akad. van Wet. te Amsterdam*, **33,** 379) finds from line contours a smaller number of Ca^+ atoms over faculæ near limb than over neighbouring points. A decrease of pressure or an increase of temperature above the faculæ is suggested. G. T. Walker (*M.N.*, **90,** 788) discusses some experiments on unstable layers in explanation of the polygonal patterns on spectroheliograms. An upward flow inside the polygons and a downward current in the bounding sheets is suggested when the instability is due to heat from below. The experiments showed how the presence of sufficient shear would lead to the development of vortices, as found in spots. Unsöld also discusses (*Zeit. f. Astroph.*, **1,** 138) the effect of convection currents in producing sunspots and granulation. The latter is less marked near the limb and may belong to lower levels. Milne (*Obs.*, **53,** 119) suggests that for $\tau = 0{\cdot}58$ St. John's work on excitation potentials and corresponding heights in the Sun indicates a temperature gradient of 110° per km. Menzel (*ibid.*, 344) disputes these results as giving an impossibly steep gradient for the chromosphere. Berlage (*Proc. Konink. Akad. van Wet. te Amsterdam*, **33,** 614) discusses the electrostatic field of the Sun on the assumption that two kinds of particles of different masses, but carrying equal positive and negative charges, are expelled radially in all directions in equal and stationary amounts. He makes certain applications to the theory of the evolution of the solar system.

Magnetic Storms.—Chapman and Ferraro have sketched (*Nat.*, **126,** 129) a new theory of magnetic storms as being connected with the *approach* from the Sun of a neutral stream of ionized particles. The

initial increase of the Earth's magnetic field and the subsequent decrease of the horizontal force are both explained. The main electric currents flow a few earth's radii away, somewhat nearer than those suggested by Birkeland and Störmer.

The usual monthly and annual summaries of observations of solar activity are published by a number of observatories. This year there are to be mentioned especially the *B.A.A. Sun Memoir* (**29**, Pt. 2), edited by Newbegin, with an account of the years 1926, 1927; Brunner's Monthly Means (*Ast. Mitt. Zürich*, 121) for 1912–1929, with values for the various latitude zones; and Favaro and Taffara's figures (*R. Oss. Astrof. di Catania*) for the variation of solar activity for the past 50 years. F. J. M. S.

The Solar Corona without Eclipse.

M. Lyot of the Meudon Observatory has made some very important and interesting observations from the summit of the Pic du Midi during the past summer. Observing at a height of 2800 metres he has secured the first definite photographic record of coronal light outside a total eclipse (*C.R.*, **191**, 834). He used a telescope stopped down to an aperture of 4 cm. (the focal length is not given), and he placed in the focal plane a disc whose radius reached beyond the Sun's radius a distance of 30″. Observing directly with an eyepiece, without the intervention of a spectrograph or even of a coloured screen, he was able to see rose-coloured prominences. Further, setting the slit of a spectrograph tangential to the limb, he was able to see superimposed on the Fraunhofer spectrum the green and red coronal lines. Where his polariscopic observations had indicated that the corona was brightest—in the NW quadrant—he was able to trace the green line to a height of 4′ above the Sun's limb, *i.e.* to a height of about 18,000 km. Visual measurements gave wave-lengths 5303·2 ± 0·1 and 6375 for the two bright lines observed, and photographs taken with a wide slit and exposures of 20 and 45 minutes gave 5302·45 and 6371·8 as the mean values, the dispersion being 30 A. per mm. at the green line.

M. Lyot also examined the polarisation of the light coming from the immediate neighbourhood of the Sun's disc. For this he used a specially sensitive fringe-polarimeter, which he had previously applied with marked success to a study of the planets (*Ann. de l'Obs. de Paris-Meudon*, **8**, 1929). This instrument indicates the plane of polarisation of the light examined and the proportion, correct to 0·001, of the light which is polarised. M. Lyot found evidence of radial polarisation up to 6′ from the limb, most marked when the sky was clear and vanishing in the presence of slight cloud. The proportion of polarised light increased rapidly as the point examined was moved from 6′ to 3′ from the limb and then it became constant up to the edge of the occulting disc. Laboratory tests failed to explain the polarisation as instrumental in origin. M. Lyot plotted on several days the proportion of polarised light at a fixed distance, 80″ from the limb in all directions

round the Sun, and got very fairly consistent results, indicating an increased brightness of the corona in one or two regions, especially in the NW quadrant, and giving minimum brightness in the polar regions. It will be a very desirable confirmation of this method of examining the brightness of the corona if it can be shown that the Moon's passage across the corona can be traced, at a conjunction where it passes very close to the Sun's limb, or at a partial eclipse.

With this test satisfied it will be recognised that M. Lyot has developed a most important method of studying day-by-day changes in coronal brightness and later, perhaps, of coronal structure. In particular, it may be hoped that the connection between prominences and coronal brightening will be elucidated. In any case M. Lyot is to be congratulated on his successful spectroscopic work, which suggests that certain problems—such as the rotation of the corona and the measurement of total radiation from the coronal lines—may be taken over from eclipse expeditions and transferred to observatories on suitable mountain-tops. F. J. M. S.

Stellar Spectroscopy in 1930.

Spectrophotometry.—The general usefulness of spectrophotometry has been increased recently by various improvements, both in method and in apparatus. Carroll and Moss (1) have described a new form of microphotometer designed to perform all the functions of existing types of instrument, with greater speed, sensitivity, and adaptability. It can be applied (amongst other things) to stellar photometry and the measurement of extended objects such as nebulæ, by means of small apertures of special shapes. The photometry of nebulæ has also been accomplished by Berman (2), who has adapted the Moll microphotometer for this purpose. His results in the case of certain planetary nebulæ include the distribution of intensity over the surface and the total integrated intensities in different wave-lengths. Mendenhall (46) describes a method of applying the spectrophotometer to variable stars, by means of which the light variation may be studied in different spectral regions. In the case of β Cephei the interesting result is found that the amplitude of variation in the ultra-violet is 50 per cent. greater than at λ 4500.

A detailed study of 90 stars (chiefly of types B and A) by Ch'ing-Sung Yü (3) deals with (*a*) four hydrogen lines, (*b*) the continuous hydrogen absorption, (*c*) the [H] and [K] lines, and (*d*) λ 3883. He has studied the variations of these lines throughout the stellar sequence and found that the intensity of continuous hydrogen absorption is proportional to the strength of the Balmer lines ; also that a correlation exists (in agreement with theory) between luminosity and the number of hydrogen lines visible. Other results, implying a drop in stellar temperatures from types B5 to B0 preceded and followed by the usually accepted increase, need further confirmation. Öhman (4) has studied short objective-prism spectra of 882 B-, A-, and F-type stars, calibrated by the prism-crossed-by-grating method and measured with a Schilt

photometer. Relations are found between hydrogen-line intensity, colour, and luminosity. Another spectrophotometric survey of the stellar sequence has been made by Miss Payne (5), who summarises results which are to appear in greater detail in a forthcoming monograph. Measures are converted into numbers of atoms by Unsöld's method, and diagrams are given showing the relative numbers of effective atoms of various elements in relation to spectral class.

Miss Anger (6) has investigated absolute magnitude effects in the two clusters, M7 and the Pleiades. Relations are found (probably due to the internal Stark effect) between total absorption of hydrogen lines, line width, line depth, and absolute magnitude.

Elvey (7), in a study of the contours of Hβ and Hγ in stellar spectra, has found a correlation of absolute magnitude with excess widths and with ratios of widths to depths in these lines. The effective number of atoms producing the absorption lines, as determined by him, is not in accord with Milne's theory in its present form.

Shapley (8) has confirmed his earlier deductions that the absolute luminosity of giants decreases with increasing surface temperature, by an investigation of the giants in M22.

Miss Williams (9) gives evidence to show that systematic differences between published contours are due to the observers' judgment in estimating the position of the continuous background.

Sampson (10) has continued his work on the effective temperatures of stars, and gives his results for 80 stars, based on measurements with a Koch microphotometer.

Theoretical investigations on the contours of absorption lines have been undertaken by Pannekoek (11) and Woolley (12).

Classification.—The classification of the O-type stars has been under investigation by Miss Payne (13, 14) and Beals (15). Both agree in separating these stars primarily into Wolf-Rayet stars and absorption O-type stars, following in the latter group H. H. Plaskett's classification. Miss Payne has apparently abandoned her previous decimal subdivisions of Wolf-Rayet stars and substituted a provisional division into two groups (designated W I. and W III.), using the relative intensities of the λ 4686 and λ 4340 bands as a basis. Beals proposes the use of the bands at λ 4511 (*He* II.) and λ 5875 (*He* I.), as being free from blends and showing satisfactory contrast with the continuous spectrum. He develops a decimal system of classification, ranging from OW5 to BWo, based on the intensity ratios of these two bands, supplemented occasionally by other subsidiary intensity ratios in ambiguous cases. Other stars, which include absorption or nebular lines, require composite designations. The interpretation of these spectra presents considerable difficulties. Beals develops his theory that the emission bands are caused by continuous ejection of gaseous material from the star, due to selective radiation-pressure ; and discusses the evidence supporting it. Miss Payne's results, on the other hand, appear not to be favourable to this theory, unless the masses of Wolf-Rayet stars are very small in comparison with their luminosities.

The origin of the absorption band near λ 4200 which appears in some stellar spectra still remains somewhat uncertain. Laboratory tests by King (16) of the 11-inch Draper telescope at Harvard show that the lens and prisms all give strong absorption in this region, sufficient to account for the observed bands. Miss Douglas (17), using similar tests on the Ottawa 15-inch refractor, finds no absorption in the optical system. She also finds that the intensity of the band in certain Cepheids varies in phase with other periodic changes, thus suggesting its stellar origin (probably cyanogen).

The identification of some previously unknown stellar lines has been made by Struve (18, 19) and by Roach (20). The former has identified some lines in γ Pegasi with strong lines of phosphorus and aluminium (Al II. and Al III.). Roach finds lines of sulphur (S II. and S III.) in various stars, reaching a maximum intensity in stars of types B5 and B1 respectively.

Schwassmann (21) has determined the spectral types of the fainter Pleiades stars. He gives a complete catalogue down to the 14th magnitude (photographic) followed by a brief discussion of colour index and spectral type in this cluster.

A comparison of giant and dwarf spectra of types K and M in the red region has been made by Miss Burwell (22); and the variations in spectral type of Polaris are briefly discussed by Miss Douglas (23).

Interstellar Matter.—The distribution of interstellar calcium, according to Eddington's hypothesis, should be approximately uniform throughout space, a condition of affairs which received some support from Struve's discovery of a distance effect on the intensity of interstellar calcium lines. This uniformity of distribution has been investigated by J. S. Plaskett and Pearce (24), who have studied the radial velocities of B-type stars brighter than 7·5 visual magnitude north of declination $-11°$ in the light of the galactic rotation theory. The velocities from both stellar and interstellar lines were used, and the interstellar calcium shown to share in the galactic rotation. Groups of stars at very different mean distances show in every case a rotational term just double that derived from interstellar calcium; indicating that each group is at twice the mean distance of its corresponding calcium cloud, and thus strongly confirming the hypothesis of the uniform distribution of the latter.

The general and selective absorption of light in space has been investigated by Trumpler (25–27) through a study of open star clusters. A comparison of cluster diameters with distance as deduced from magnitudes and spectral types suggests a general absorption of the order of 0·7 mag. per 1000 parsecs. The existence of a selective absorption of about 0·32 mag. per 1000 parsecs is supported by the increase of colour excess (*i.e.* the difference between the colour index of a star and the normal colour index for its spectral type) with distance, as observed in these clusters. The apparent contradiction with Shapley's earlier results is explained by the supposition that the absorbing matter is confined to our stellar system, with a strong

galactic concentration. The relation between colour excess and distance has also been studied by Schalén (28) in the cluster N.G.C. 663. He fully confirms Trumpler's work, though his value of the absorption coefficient is slightly smaller. Öhman, in his study of B-, A-, and F-type stars previously mentioned (4), also confirms the existence of selective absorption in low galactic latitudes. He finds the absorption of λ 3912 relative to λ 4415 to be 0·19 mag. per 1000 parsecs.

Distant spectroscopic binaries form a crucial test of monochromatic absorption, since they should show interstellar lines between the extreme positions of the oscillating stellar lines. The star U Ophiuchi has been examined by Struve (29) from this point of view. He finds interstellar lines of both calcium and sodium, in spite of the comparatively late spectral type (B8, Harvard), which is in agreement with Eddington's hypothesis.

Radial Velocities.—Radial velocity measures during the year have not been very numerous. The principal list comes from the Lick Observatory's station in Chile, in which Neubauer (30) gives the results for 213 B-type stars and 138 of types A–M observed during the period 1924–1929.

Albrecht's accurate wave-length measures in the typical A-type star γ Geminorum (45) will be of considerable use in deciding the normal wave-lengths to be used for radial velocity work on stars of this type.

A few spectroscopic binaries of special interest have received individual attention. Mendenhall (46) in a study of β Cephei finds that the short-period radial velocity variations can more reasonably be attributed to pulsations than to orbital motion, but that γ also shows variations of long period, indicating that β Cephei is the brighter component of a binary of period approximately twenty years.

Trumpler (31) gives provisional data for Boss 4444 (in the centre of N.G.C. 6383), which is a new spectroscopic binary with both components of similar magnitude and spectrum.

The secondary star in RS Canum Venaticorum is shown by Joy (32) to be peculiar in being very large and massive for its absolute magnitude and type. Its density appears to be intermediate between the densities of giants and dwarfs.

Carpenter (33) finds an abnormally high eccentricity (0·474) for the orbit of U Cephei, with a major axis inclined at 65° to the line of sight.

A study of β Lyræ by Baxandall (44), which is mentioned in a later paragraph, includes a series of radial velocity determinations, but without any attempt at revising the orbit.

References to other spectroscopic binaries are given at the end of this note (34–38).

Bright Line Stars.—Papers relating to the spectra of Wolf-Rayet stars have already been referred to under the heading of "Classification." It might be mentioned, in addition, that a complete list of

these objects, including the nuclei of 39 planetary nebulæ, is given by Miss Payne (13), and that Beals (15) tabulates all available information concerning the wave-lengths and identifications of Wolf-Rayet emission bands.

The spectrum of π Aquarii is described by Higgs (39), who deals with the variations in intensity and radial velocity of the bright hydrogen lines. Contours of these lines are given, reduced from microphotometrical tracings, and also a bibliography of previous work done on this star. The observations are at present insufficient to ascribe any definite period to the variations. Some unpublished observations of this star, kindly supplied by Lockyer, confirm Higgs's main results of intensity variations apart from those of short period. In addition they suggest an approximate period of 1194 days for the changes.

A detailed study of bright lines in the spectra of variable stars of types Me and Se has been made by Merrill and Burwell (40). Wave-lengths and identifications of 58 lines are tabulated, several of which have not been previously recorded. These include some "forbidden" iron lines and a Mg triplet in the ultra-violet. Intensity variations form the main subject of investigation—ratios being observed rather than individual intensities, to avoid photometric difficulties. In particular, the intensity ratios $H\gamma : H\delta$, $\lambda\ 4308 : \lambda\ 4202$, and $\lambda\ 4571 : \lambda\ 4308$ show striking variations throughout the light period.

Brief descriptions of 10 Be and Ae stars, discovered at Mount Wilson, are given by Merrill (41), including one not previously recorded as having emission lines (HD 218393). Two other previously unrecorded bright-line stars are investigated by Lockyer (42), namely, θ Coronæ Borealis and HD 224544, both of which show bright hydrogen lines. Struve and Elvey (47) have found a fine hair-like emission in the centre of $H\beta$ in the star ϵ Aurigæ which has not been previously noticed.

Continuous observations of the star HD 20336 throughout a complete cycle have been made by Lockyer (43). Intensity differences between the red and violet components of $H\beta$ (emission) are recorded by both eye estimates and wedge measurements. These yield a curve of variations of well-determined form giving a period of 1568 days. (The radial-velocity period previously found by Curtiss was 1710 days.)

Special Studies of Individual Stars.—Several individual stars have formed the subjects of more or less detailed investigations. In a posthumous memoir on β Lyræ, Baxandall (44) has given the results of three series of spectrograms taken at Cambridge and Allegheny. Detailed descriptions are given of the two absorption spectra as well as the emission bands, including wave-lengths, radial velocities, and periodic changes. A tentative hypothesis is suggested to explain the spectra, which includes the presence of a third body having the nature of a Trojan planet.

Albrecht (45) has made accurate measurements of over 900 lines in the spectrum of γ Geminorum (a typical Ao star) over the range λ 4250–λ 4723. The average probable error is given as 0·02 A., and estimated intensities are given on a modified Rowland scheme.

The study of β Cephei by Mendenhall (46) has already been mentioned in other connections. It includes extensive radial velocity measurements and spectrophotometric observations of the light curve in different wave-lengths.

The spectrum of ϵ Aurigæ has been investigated by Struve and Elvey (47) and by Adams and Sanford (48). The former find changes in the character and intensity of some of the absorption lines during the eclipse, but no appreciable change at other times. The 27·1 year radial-velocity period is confirmed, and, in addition, irregular oscillations with an approximate period of 110 days which are independent of the eclipse.

Spectroscopic Parallaxes.—The determination of spectroscopic parallaxes has been taken up at the Commonwealth Observatory, Canberra. Rimmer (49) has determined the parallaxes of 350 B-type stars by a method similar to Edwards's modification of the one originally devised by Adams and Joy. A full discussion of the method and of further slight modifications is given, together with a comparison with other parallaxes.

Edwards (50) has published the parallaxes of 175 B-type stars in continuation of a series of earlier results.

Öhman's study of short objective prism spectra (4, 51) with a Schilt photometer confirms his use of hydrogen-line intensities as a criterion for luminosity in B- and A-type stars. He also extends the relation to A5–F8 stars by combining the hydrogen intensities with colour equivalents, and gives absolute magnitudes for about 800 stars in the Greenwich Polar Zone.

In this connection also might be recalled the previously mentioned work on hydrogen-line contours of Elvey (7), who uses his results to determine the absolute magnitudes of several stars ; of Miss Anger (6) on absolute magnitude effects as determined in galactic clusters ; of Ch'ing-Sung Yü (3), who confirms his correlation between luminosity and number of hydrogen lines visible ; and, finally, the relation between distance and colour excess as investigated by Trumpler (25–27) and Schalén (28).

Axial Rotation.—The possibility of measuring the axial rotation of stars through a study of line contours has recently come into prominence. The theoretical effect of rotation is to produce lines of " dish-shaped " (*i.e.* broad and shallow) contours, and Elvey has shown that actual observed contours in many stars agree well with the theoretical shapes for rapidly rotating stars. Struve (52) has shown that in spectra containing lines of this type the broadening is proportional to wave-length (in accordance with the Doppler effect), and

that in spectroscopic binaries there is a correlation of line-width with period and amplitude. The suggestion that lines of this observed type are caused by axial rotation is thus strongly supported. Struve finds in the case of α Virginis (bright component) an equatorial velocity of rotation of about 200 km./sec., but such extremely rapid rotations are only found amongst the earlier spectral types.

Elvey (53) describes a graphical method of obtaining theoretical contours of λ 4481 for different rotational speeds, and compares the results with observed contours in 59 spectra of types O to F. He deduces an average equatorial velocity of 60 km./sec. The individual values range from 0 to 200 km./sec., and are checked by means of measures of the same stars by Struve, with which they are in good agreement.

Observations on U Sagittæ by Joy (35) include an examination for rotational effects. He deduces velocities of rotation at the limb of 60 and 62 km./sec.

Kreiken (54) has used Elvey's results to deduce a relation between period of rotation and angular semi-diameter (reduced to a distance of 10 parsecs).

Theoretical.—Theoretical work during the year has centred mainly round the conflicting theories of stellar structure held by Eddington and Milne. By commencing the investigation with known observed quantities at the surface of a star and working inwards towards the centre, Milne claims to clear theory of all special assumptions, thus regarding his results as legitimate deductions rather than as hypotheses. He is led to the conclusion that stellar structures may exist in two types of stable configurations: firstly, stars of high luminosity (normal giants and dwarfs) with a central core of extremely high density, and, secondly, "collapsed" stars (white dwarfs) which occur if the luminosity (and hence light pressure) is below a certain critical value. He disagrees with Eddington's theoretical basis for the mass-luminosity relation, and considers that its actual existence as observed in nature is more closely related to the mechanism of energy liberation in the central core.

Eddington, on the other hand, denies some of Milne's fundamental premises, and, in addition, points out the serious discrepancy between the required opacity of the stellar matter and physical theory.

It is scarcely feasible to give here detailed summaries of all the papers which have appeared, but a list of the more important papers on these and kindred subjects is appended at the end of this note (55–68).

In connection with theoretical spectroscopy, the appearance must be mentioned here of two new volumes of the *Handbuch der Astrophysik* which have been published during the year. The two together form vol. iii. of that work, and complete pt. iii. of the *Grundlagen der Astrophysik.*

D. L. E.

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(40) P. W. Merrill and C. Burwell, "Behaviour of Bright Lines in the Spectra of several Long-period Variable Stars," *Ap. J.*, **71**, 285.
(41) P. W. Merrill, "Notes on the Spectra of Ten Bright-line Stars of Classes B and A," *Ap. J.*, **72**, 98.
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(53) C. T. Elvey, "The Rotation of Stars and the Contours of Mg^+ 4481," *Ap. J.*, **71**, 221.
(54) E. A. Kreiken, "Note on the Axial Rotation of Stars," *M.N.*, **91**, 251.
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(56) Sir A. S. Eddington, "The Effect of Boundary Conditions on the Equilibrium of a Star," *M.N.*, **90**, 279.
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(59) ———— "The Dissociation Formula according to the Fermi-Dirac Statistics," *M.N.*, **90**, 769.
(60) ———— "The Analysis of Stellar Structure," *M.N.*, **91**, 4.
(61) Sir A. S. Eddington, "The Effect of Stellar Boundary Conditions : A Reply," *M.N.*, **90**, 808.
(62) ———— "The Opacity of Extended Stellar Envelopes," *M.N.*, **91**, 109.
(63) H. Jones, "Deviations from Boyle's Law in Stellar Interiors," *M.N.*, **90**, 293.
(64) N. Fairclough, "Numerical Integration of Emden's Polytropic Equation of Index Three," *M.N.*, **91**, 55.
(65) R. H. Fowler, "The Solution of Emden's and Similar Differential Equations," *M.N.*, **91**, 63.
(66) T. G. Cowling, "On a Point-Source Model of a Star," *M.N.*, **91**, 92.
(67) M. Bronstein, "Note on the Temperature Distribution in the Deep Layers of Stellar Atmospheres," *M.N.*, **91**, 133.
(68) Sir J. Larmor, Sir A. S. Eddington, and E. A. Milne, Correspondence on the Mass-Luminosity Relation in *Observatory*, **53**, 113, 167, 208, 238, 305, 342.

Double Stars.

Measures and New Pairs.—A memorial volume containing the double star observations made by the late Professor Leavenworth has been published by the University of Minnesota. For over forty years Professor Leavenworth observed double stars, mostly with the 10½-inch refractor at Minneapolis, but also with other telescopes, including the 40-inch at Yerkes and the 26-inch of the Leander McCormick Observatory. The measures are given in the form of 2988 annual means for 1185 double stars. Most of the observations have been published before in various periodicals, but several hundred measures are new. The volume also contains 341 annual means for 289 stars from measures made by the late Professor Beal.

Professor Van den Bos gives, in *B.A.N.*, 188, his tenth list of new double stars with separation less than 5″. It contains 189 stars, B1714–1902. In the same publication he gives the measures for 349 fainter or wider pairs which he has discovered in the course of his search. His observations of previously known stars are being published in the Union Observatory *Circulars*. No. 83 contains 1314 measures

of 319 pairs. These measures are only published when the star has been measured on at least 4 nights.

The observations of W. Rabe made at Munich in the years 1925–27 have been published in *A.N.*, **239**, 369, and **240**, 17. The measures concern 362 stars, of which 269 are Σ, 78 OΣ; the separation of 107 is under 1″·0. A discussion of the systematic errors in distance and position angle is made by comparison with the measures of other observers.

In Appendix III., 2, to the Vatican Section of the Astrographic Catalogue, about 2800 measures of 1827 double stars, with separations up to 15″, between declinations 53° 55′ and 58° 55′, are given. This increases the number of double stars catalogued in the Vatican Zone to 3092. A statistical discussion of the number of optical systems is given. The catalogue gives special reference to previously known double stars.

Other double-star measures are indicated in the following table :—

Observer.	Reference.	No. of Stars.	Notes.
Aller, R. M.	*A.N.*, **238**, 71	39	Σ, on 6 nights.
Barton, S. G.	*A.J.*, **40**, 181	98	Helsingfors Zone of Astr. Cat.; 26 new.
Buchar, E.	*Mem. de la Soc. Roy. de Bohême de Prague*	51	Mostly Σ, 3 or more nights.
Commendantoff, N.	Pulkovo	77	Most Σ, many wide.
Doberck, W.	*A.N.*, **239**, 49	80	Many Σ, 3 or more nights.
Espin, T. E. and Milburn, W.	*M.N.*, **90**, 317	41	Previously known.
		38	Espin new.
		39	Milburn new.
Jonckheere, R.	*Journ. des Obs.*, **13**, 76	9	New.

Aitken has remeasured *o* Ceti (*P.A.S.P.*, **42**, 60). He finds that there has been no definite change in either separation or position angle since 1923. As the companion was not seen in some intermediate years he concludes that it is variable. Sirius has been measured by Aitken (*P.A.S.P.*, **42**, 123) and by Jonckheere (*loc. cit.*).

Orbits.—The following table gives the principal elements of new orbit determinations :—

Star.	Computer.	Reference.	P. Years.	*a.* ″	*e.*
Krueger 60	Huffer, R. C.	*A.J.*, **40**, 183	44·5	2·362	0·41
24 Aquarii	Finsen, W. S.	*U.C.*, 81	51·3	0·525	0·910
β 232	Kuiper, G. P.	*B.A.N.*, 195	91·2	0·368	0·326
Σ 228	..	..	149·6	0·917	0·290
OΣ 77	..	..	122·6	0·472	0·170
OΣ 82	..	..	487	1·72	0·556

The masses of the components of Krueger 60 are found to be 0·18, 0·22 in terms of the sun, and the absolute magnitudes 11, 14.

P. van de Kamp, in *Pop. Astr.*, **38**, 478, has determined the masses and absolute magnitudes of two stars as follows :—

	Masses.	Absolute Magnitudes.
β 648	1·15, 0·24	4·6, 8·1
99 Her.	2·01, 0·08	3·9, 8·4

The mass of the fainter component of 99 Her. is extremely small, but its probable error is $\pm$ ·18. With regard to 24 Aquarii the eccentricity is large, and a rare opportunity to determine the parallax by spectroscopic observations was missed in 1925, when the relative radial velocity changed very quickly from $-$ 20 to + 20 km./sec. G. P. Kuiper (*B.A.N.*, 195) suggests that the triple system ξ Scorpii and the double star Σ 1999 form one system, with a parallax of 0″·04 and an apparent separation of 280″.

An alternative derivation of the elements of an orbit by Kowalsky's method is given in *M.N.*, **90**, 534, by W. M. Smart. In *U.C.*, 82, J. E. Kerrich discusses the determination of the orbit of a binary from a consideration of spectroscopic observations and measurements of position from photographs, on the assumption that only one star of the pair produces an effect on the spectrograms and photographs.

E. Hertzsprung (*B.A.N.*, 208) has discussed the orbital motion to be expected in double stars of given magnitude, separation, and proper motion. As might be expected, he finds that the proper motion is a most important factor. He obtains the formula

$$\log v = \log \mu - \tfrac{1}{2} \log s - 0{\cdot}1\,(m + c) \pm 0{\cdot}3,$$

where v, μ, s are the orbital motion, proper motion, and separation in seconds of arc, m the magnitude, and c a constant, with the value 2 or 1 according as m is visual or photographic. He applies the formula to 35 pairs given in the Greenwich Astrographic Catalogue, vol. v., with s varying from 2″·4 to 1275″ and μ from ″·062 to 1″·396.

Miscellaneous.—In *P.A.S.P.*, **42**, 244, Aitken announces that the manuscript of his new Double Star Catalogue has been completed. The limit of $-$ 30° Dec. has been strictly adhered to, although Burnham's Catalogue extended to $-$ 31° and actually contained a few stars south of this limit. In deciding which stars are to be included, the formula $\log \rho = 2{\cdot}8 - 0{\cdot}2\ m$ has been used to fix the limit of separation ρ for magnitude m. This gives $\rho = 10''$ for $m = 9$—an ample allowance; nevertheless, 642 of the first 2000 stars in Burnham's Catalogue have been excluded by it. The new catalogue has 17,180 entries and includes 7500 to 8000 not in Burnham's Catalogue, which has 13,665 entries.

In *Pop. Astr.*, **38**, 406, Dirk Reuyl discusses the separation of double stars as measured on photographic plates. As is known, for faint images the components appear too near, for over-exposed images too far apart. On the average he finds that for a separation of 0·13 mm. the distances are too small by ·005 $\pm$ ·001 mm. For faint images the displacement might be twice as large. (See also A. Vyssotsky, *Pop. Astr.*, **38**, 478.)

In *M.N.*, **90**, 212, 306, E. A. Kreiken finds that for giant stars there is a greater frequency of double stars among the early types, while for dwarfs there is maximum frequency along the central line of the Russell-Hertzsprung diagram. In *A.N.*, **238**, 373, Kreiken challenges the result of Shajn and Vogt that the mass ratio in binary stars increases with advancing spectral type MK . . A . . KM. Shajn replies to this in *A.N.*, **240**, 305. J. J.

Variable Stars.

As usual, a great amount of matter concerning variable stars has appeared in print during the past year. In this brief note no attempt has been made to do more than to give some short abstracts of a few of the more interesting special studies that have been published since the date of the last Report of the Council.

Eclipsing Variables.—A. H. Joy, in *Ap. J.*, **71**, 336, gives the results of a spectrographic study of U Sagittæ, carried out at Mt. Wilson. This is one of the brighter of the eclipsing variables, and has a period of about 3·38 days. The primary is of type B9. It suffers total eclipse by the larger, fainter, and less massive companion, the spectrum of which can be studied during the hundred minutes of total eclipse. It proves to be of type G2, with a mass about one-third that of the primary. While the disc of the fainter star encroaches upon that of the brighter star, the velocities are affected by the rotation of the latter. With the inclinations and the duration of eclipse indicated by Fetlaar's uniform and darkened solutions, the values of the rotational velocities at the limb are 60 and 62 km./sec. respectively. The radius of the smaller star, corresponding to a velocity of 60 km./sec., is 2,790,000 km. Further details of the absolute dimensions and luminosities of the system are given in the paper.

Similar data concerning another eclipsing variable, RS CVn, are given by the same author in *Ap. J.*, **72**, 41. The spectrum of the primary is F4, that of the secondary *d*G8. In this case also the eclipse is total, lasting 3·7 hours. The spectroscopic absolute magnitudes are, respectively, 3·5 and 4·5, and it is remarked that the fainter star is exceptionally large and massive for its absolute magnitude and spectral type.

Two interesting papers on the eclipsing variable Y Cygni appear in *M.N.*, **90**, 754, and **91**, 212, respectively. In the first R. O. Redman shows that spectrograms of this star, taken at Victoria, indicate an orbital eccentricity and motion of periastron in close agreement with photometric results. The velocity of the centre of gravity of the system has been found to be changing, indicating the presence of a third body, though the mass and luminosity of the latter must be relatively small, no sign of its spectrum being detectable. In the second paper H. N. Russell and R. S. Dugan discuss the probable cause or causes of the apsidal motion, which is of the rather long period of 46·8 years. The two most likely causes are ellipticity of the eclipsing

stars and the attraction of a third body. The former would account for the observed apsidal motion, though the data are not sufficient to evaluate it with certainty. The difficulty of the third-body explanation is that the observed period is too long. Such a body, even if of considerable mass, must have a short period in order to produce as great an apsidal motion as a very small ellipticity of the principal stars.

E. F. Carpenter (*Ap. J.*, **72**, 205), from a study of 34 spectrograms of the brighter component of the eclipsing variable U Cephei, derives elements which indicate an orbit of abnormally high eccentricity (0·474). The period is shown to increase steadily, with an oscillation of a few seconds' amplitude and an irregular period of about a dozen years.

Cepheids.—In *H.B.*, 872, H. Shapley and Cecilia Payne reply to some objections to the validity of the period-luminosity relation, raised by Dr. Schilt. The latter had maintained that there was good reason to believe that, in the case of the classical Cepheids, there was a subdivision into two groups, those with periods a little longer than ten days being absolutely fainter than those with periods shorter than ten days.

The authors point out that the data used by Schilt, especially in relation to the *c*-characteristic, were incomplete, and conclude, from a study of more extensive material available at Harvard, that there is no ground for the suggestion that the spectra and apparent magnitudes of galactic Cepheids are not in accord with the luminosities suggested by the period-luminosity curve in isolated stellar systems.

Continuing his investigations of the photographic light curves of Cepheid variables, L. V. Robinson (*H.B.*, 872) discusses the question of the existence of a third group of Cepheids, with periods exceeding thirty days, additional to the two groups already suggested by Ludendorff. The author shows that, while there is a definite relation between period and sharpness of rise for stars with periods below thirty days, no such relation exists for periods above forty days, which may or may not point to a radical difference in type of these latter.

The same author contributes an interesting note on some changes observed in the light curve and period of the Cepheid XY Cassiopeiæ (*loc. cit.*).

Harlow Shapley, in *H.B.*, 875, gives the results of an investigation of the changes in the light curve of the Cepheid BF Ophiuchi over a period of thirty years. These changes, suspected before, are very definitely established in this paper, and the author remarks that the chief value of the work is the warning it gives that, in classifying the curves of Cepheid variables, we must allow for a considerable margin of variability for the individual stars.

Cecilia Payne, in *H.B.*, 876, discusses the relation of period to mean density for Cepheid variables. The three correlations that are commonly used in examining the physical condition of these objects are (1) the period-luminosity law, (2) the period-spectrum relation, and (3) the mass-luminosity law. The author considers the closeness of these

three correlations, and concludes that there is an inherent dispersion in the first two.

H.C.O. Circ., 351, consists of a very complete study by P. ten Bruggencate of the variations in light, colour, and radial velocity of Y Sagittarii. The data available to the author were unusually extensive, and he remarks that this star is one of the most completely observed of all the Cepheids.

In *M.N.*, **90**, 806, A. V. Douglas gives the results of microphotometer measures of the spectrum of α Ursæ Minoris at various times during its period of light variation. The latter is about $3^{d}\cdot97$, the amplitude of the variation being $0^{m}\cdot17$. Dr. Douglas finds that the spectrum ranges in type from F7 to F9, the average, F8, being in agreement with that adopted in the H.D. classification. Further, the variations in the spectrum accompany the changes in magnitude, the maximum (F7) being about at the phase of maximum light and the minimum (F9) near the time of minimum light.

In *Ap. J.*, **72**, 46, Roscoe F. Sanford deals with variations in the radial velocities of three Cepheid variables—W Geminorum, U Aquilæ, and DT Cygni. It is found that the velocity curves of the two last-named are mirror images of their light curves, *i.e.* maximum velocity coincides with minimum light and *vice versa*. For W Geminorum the interval between maximum and minimum velocity is nearly a day less than the mean interval between minimum and maximum light. Since the period derived from the radial velocities shows that maximum velocity coincides in the mean with minimum light, it follows that, with this period, minimum velocity precedes maximum light by nearly a day.

Results of colour measures of δ Cephei, made visually with a blue-wedge colorimeter by B. Fessenkoff, are given in *A.N.*, 5722. From his observations the author concludes that the variation of temperature between maximum and minimum is nearly 1400°. From the available data there is not enough evidence to show whether the maxima of light and temperature coincide, but the difference in time between them, if any, is shown to be very small.

In *M.N.*, **90**, 798, A. V. Douglas discusses the anomalous behaviour of the cyanogen band (near λ 4200) in the spectra of the three Cepheid variables, RT Aurigæ, η Aquilæ, and α Ursæ Minoris. The changes of its intensity during the cycle are similar to those of the enhanced lines, and suggest that the CN molecule is in the ionised state. Two factors would then be working in opposite directions, the increasing temperature bringing about a dissociation of the molecule, but producing a larger percentage of ionised molecules among those remaining, while fall in temperature would reverse the two tendencies. The only explanation of the abnormal behaviour of CN that suggests itself at present is that, like the enhanced lines of iron, titanium, and scandium, the band has its origin at a very high level in the stellar atmosphere.

D. B. McLaughlin, in *A.J.*, 932, deals with the relations between light changes and velocity changes in variable stars other than those of the eclipsing type. He points out that, in the case of the Cepheids,

the maxima of light are almost coincident with the minima of radial velocity, but that in stars of the Mira type the times of both maxima are nearly the same. He then takes the difference in time between light maximum and velocity minimum, and, expressing the values thus obtained as a fraction of the period, plots the results on a graph, with the logarithm of the period as abscissa and the ratio above named as ordinate. The plotted points fall along a parabola with axis vertical and vertex on the x-axis at a point corresponding to a period of one week, which, the author points out, is near the position of maximum frequency of period for the Cepheids. The conclusion reached is that all variables of the non-eclipsing type form a connected sequence, and that the Cepheid type occurs at the point of maximum stability of the pulsations of the stars which are supposed to produce the variations of light.

Long-period Variables.—In *Ap. J.*, **71**, 285, P. W. Merrill and Cora Burwell discuss the behaviour of bright lines in the spectra of thirteen long-period variables, ten being of type Me and three of type Se. Special attention is given to the relative intensity of pairs of lines. It is found that the intensity ratio $H\gamma : H\delta$ in Me stars varies with phase in a striking manner. To take a typical case : at one-fifth of the period before maximum (phase $-0{\cdot}2$) the ratio is 1 : 8 ; it rises rapidly to 1 : 2 at $-0{\cdot}05$, then remains nearly constant until $+0{\cdot}2$, after which it again rises rapidly to 2·5 : 1 at about $+0{\cdot}4$. In Se spectra the ratio has a minimum of 2·5 : 1 at $+0{\cdot}07$, with higher values earlier and later.

As regards the apparent velocities, derived from the blue-violet lines, an algebraic decrease at and shortly after light-maximum, with a flat minimum 30–80 days after light-maximum, are typical features. A maximum in the displacement-curve about 30 days before light-maximum is probably also typical. The range in apparent velocity is about 10 km./sec., probably being larger for the stars with the shorter periods. The phenomena appear essentially the same for Me and Se variables.

Most of the bright lines behave as if they had little dependence on the photosphere. In discussing the effects of band-absorption, the existence of titanium oxide above the level at which the bright lines are produced is suggested as a working hypothesis to explain the abnormally low intensities of $H\alpha$, $H\beta$, and $H\gamma$ relative to $H\delta$. The bearing of the behaviour of the bright lines on theories of long-period variables is briefly discussed.

In *H.B.*, 872, Gerasimovič and Shapley investigate the relation between colour and period for thirty-eight long-period variables. The conclusion reached is that, while for stars of classes M and S no such relation appears, those of class N show a marked increase of colour index with period.

Some interesting comparisons of the photographic and visual light-curves of a few long-period variables are given in two papers in *H.B.*, 872. In the first Miss Cannon discusses the case of Mira Ceti, and finds that

the colour index is greatest about 40 days before maximum, and least from 100 to 150 days after maximum. In the second paper Leon Campbell and Cecilia Payne make a similar comparison in the case of seven other variables. The results for each star differ somewhat widely, and the only definite inferences which can be drawn are that the range in colour is greatest for stars of greatest magnitude range, and that for the stars for which the heights of successive visual maxima differ, photographic maxima show a similar effect. Therefore the difference is one of brightness, not of colour, when successive maxima differ in height.

In *M.N.*, **90**, 65, Eddington and Plakidis endeavour, by an interesting method of analysis, to determine the nature of the periodic changes in period of long-period variables, taking Mira Ceti and χ Cygni as typical examples. This method of analysis is further developed and extended to eight more stars by Cecilia Payne and Leon Campbell in *H.B.*, 875. The authors find that the evidence obtained for these eight stars does not lead precisely to the same results as those derived by Eddington and Plakidis from a study of the two objects above named. Further, there are indications that the observational and practical difficulties in using this method of analysis are very great, chiefly because periodic inequalities are of very long period, and the " true " period of any given star may therefore be in serious doubt.

R. G. Aitken, in *P.A.S.P.*, **42**, 60, gives measures of the position-angle and distance of the companion of Mira Ceti, obtained with the 36-inch refractor at the end of 1929. The measures appear to demonstrate that little or no motion has taken place since the companion was first seen and measured in 1923. Professor Aitken remarks on his failure to see the star on several occasions, during the past few years, when it should have been visible, and suggests the possibility that it is itself a variable star of irregular period. The position of the companion at 1929·98 is given as P.A. = 134°·7, Δ = 0″·86 (two nights).

A paper on changes in the period of the long-period variable R Hydræ, by R. Müller, appears in *A.N.*, 5669. This object is a naked-eye star at maximum, and records go back to the year 1662. From these early observations Ludendorff had deduced that the period was then 486 days and that it increased to 507 days about 1708. In 1784 the period was about 500 days, but thereafter diminished rapidly and fairly uniformly until at the beginning of the present century it was scarcely more than 400 days. Müller now shows that it has once more begun to increase, and, as a formula for the dates of maximum, gives J.D. $2423040{\cdot}0 + 411{\cdot}7\,E + 0{\cdot}8838\,E^2$. W. H. S.

The Expansion of the Universe.

We may, if we like, regard the " expansion of the universe " as an observational phenomenon independent of theories of curved space. This is a deviation from the historical order ; for when in 1917 W. de

Sitter put forward his famous theory, predicting large and predominantly receding velocities of distant objects, he could quote only 3 measured velocities of spiral nebulæ in support. By 1922 V. M. Slipher had furnished 40 radial velocities of spirals, of which only 5 were negative. Interesting additions have since been made at Mt. Wilson, including some very large receding velocities of faint and presumably distant nebulæ. The few negative velocities have disappeared, or been reduced to insignificance, by the recognition of our own orbital motion round the centre of the galactic system. It appears, then, that the spiral nebulæ are running away from us with remarkable unanimity; the speed of recession increases with increasing distance, the amount being roughly 500 km. per sec. per megaparsec distance. At this rate they will double their distances from us every 1400 million years, and scatter apart from one another as much as they scatter away from us. Whether or not this represents an "expansion of space," it is an expansion of the material universe alarmingly rapid to those who were becoming accustomed to thinking in terms of billions of years.

The theoretical explanation of this effect is due to de Sitter, but the actual hypothesis or law involved in it is due to Einstein. In order to meet certain philosophical difficulties connected with absolute rotation, Einstein in 1917 amended his law of gravitation by the addition of a minute "cosmical term," so as to read $G_{\mu\nu} = \lambda g_{\mu\nu}$ instead of $G_{\mu\nu} = 0$. It can be shown that this adds to the ordinary gravitational attraction of bodies a repulsion from the origin varying directly as the distance. In general this repulsion will gain the upper hand at sufficiently great distances; that essentially is de Sitter's explanation of why these remote astronomical objects are being scattered away from us (and from each other). Einstein's original reason for introducing $\lambda g_{\mu\nu}$ would probably not be pressed to-day. But the term plays a fundamental part in Weyl's and subsequent developments of Einstein's theory. It has been shown by me that the term is necessary if the principle of relativity is pushed to its logical conclusion, so that size (or scale of magnitude) is relative and not absolute. The law $G_{\mu\nu} = \lambda g_{\mu\nu}$ is a simple expression of the fact that our survey of the world is made by instruments which are themselves part of the world; so that extensions are not measured absolutely but relatively to extensions implicit in the structure (and especially the curvature) of space-time. In short, when the law of gravitation is taken to be of this form, a rational explanation of it can be given.

Thus far the finitude of space has not been mentioned; but the conception of a repulsive force, increasing indefinitely as the distance increases, acutely raises the question, What is to be done about infinity? Within a sphere of uniform density the gravitational attraction is proportional to the distance from the centre; it is therefore proportional to the repulsion, which likewise varies as the distance. Thus there is a particular density of uniform distribution for which the attraction and repulsion will balance throughout. It is well known that density involves curvature of space, and in this case, if the

uniform distribution extends far enough, space closes up, forming a sphere of a definite radius. The distribution of matter of uniform density, filling a closed space, and in equilibrium owing to the balancing of gravitational attraction and cosmical repulsion, is known as an "Einstein world." Both the radius and the density must have a particular value fixed by the constant λ; but, of course, these values remain unknown until we have some observational means of determining λ. In contrast we can set a "de Sitter world," which is entirely empty, so that the cosmical repulsion acts without opposition. Neither world could be seriously suggested as an exact representation of the universe; but the former will be the appropriate first approximation if the masses of the spiral nebulæ are on the average sufficient to restrain by their mutual gravitation the scattering tendency, and the latter will be the appropriate model if gravitation between the galaxies is small compared with the scattering term. Since we observe a recession of the galaxies the latter approximation has been preferred.

There was an obvious inconvenience in working with only two model universes, one of which admitted matter but no motion and the other motion but no matter; and efforts were made to find intermediate solutions. This was made rather more difficult by the fact that de Sitter employed a transformation of time-reckoning which obscured the connection of his world with Einstein's. Nevertheless solutions were found, published, and forgotten, buried like a needle in the haystack of relativity literature. Such a solution was given by A. Friedman in 1922. In 1927 Abbé G. Lemaître not only rediscovered the series of solutions intermediate between Einstein's and de Sitter's, but worked out the astronomical consequences in a complete manner, obtaining results of remarkable interest. This paper also remained unknown. Wider publicity was obtained by H. P. Robertson, who again found the solutions in 1929; but his point of view was mathematical and logical rather than astronomical.

Lemaître's paper came to light again in 1930 in connection with an informal communication given at a meeting of the Society by de Sitter. Making (as I think) a rather excessive estimate of the masses of the nebulæ, de Sitter propounded the dilemma that the actual universe apparently contained enough matter to make it an Einstein world and enough motion to make it a de Sitter world. This naturally called attention to the need of intermediate solutions for handling such a question. Some of my remarks in the discussion were reported, and Lemaître (who had once been a student of mine) wrote to me on the subject, drawing attention to his paper; I was at that time working with G. C. McVittie on the question whether Einstein's world is stable, using Robertson's paper as a basis. The elegance and completeness of Lemaître's work was recognised by de Sitter and myself, and it has been the subject of papers by both of us. I pointed out that it was immediately deducible from his formulæ that Einstein's world is unstable, so that an expanding or a contracting universe is an inevitable result of Einstein's law of gravitation. The question remains whether

it could have been predicted that expansion rather than contraction will actually occur. I showed that conversion of matter into radiation tends to retard the expansion and therefore cannot be the cause. The effect of the gradual condensation of the matter into galaxies has been examined by G. C. McVittie and W. H. McCrea. Their first conclusion was that this also would tend to cause contraction; but recently McVittie, in a far-reaching investigation, has obtained the opposite result, so that it seems likely that this is what originally started the expansion. The question, however, is one of extreme difficulty, and McVittie's result may not be definitive. It should be understood that the discussion concerns only the initial cause which decided between expansion and contraction. Once started, the expansion or contraction continues at an accelerated rate in accordance with Einstein's law of gravitation, and without any other maintaining causes.

" Lemaître's world " is also a model in that it represents the universe as a uniform spherical distribution of matter; there is no reason why the actual shape should not be highly irregular. But it serves to exhibit the evolution of a universe, starting presumably as an Einstein world in equilibrium but unstable, and progressing towards de Sitter's world as the ultimate limit when the expansion has reduced the density so much that it may be treated as empty so far as gravitation is concerned. To picture it we may imagine the nebulæ to be embedded in the surface of a rubber balloon which is being inflated, so that objects " at rest " are actually becoming more and more widely separated. An interesting point is that the random motions of the galaxies will decrease as the expansion increases, so that if the expansion of the universe is already large, the motions of the spiral nebulæ should correspond to the cosmical repulsion without much masking by other effects. The expansion of space affects only the separation of the galaxies; it does not cause the galaxies themselves to become any larger. (De Sitter disagrees with me on this point.) The following numerical results rest on the provisional assumption that the observed recession of 500 km. per sec. per megaparsec corresponds to the cosmical repulsion undiminished by any important gravitational attraction between the nebulæ. The initial radius of space was 1200 million light-years and the whole mass of the universe is $10^{22} \times \odot$. The present radius is practically incalculable, but is supposed to be considerably larger. The radius increases with the time in geometrical progression, and ultimately objects must separate at a rate greater than the velocity of light; there is no contradiction in this, for the separation corresponds not to dynamical motion but to inflation of space. Objects separating faster than the velocity of light are cut off from any causal influence on one another, so that in time the universe will become virtually a number of disconnected universes no longer bearing any physical relation to one another. It was one of the advantages of de Sitter's original representation that it exhibited this gradual disappearance of parts of the universe " below our horizon " more prominently than Lemaître's representation does. Probably a great part of the universe is already below our horizon. We might still see

it owing to the lag of light-time—that is to say, we should see the events which happened in it before it passed below the horizon, but light from the events " now " happening will never reach us.

We can, if we prefer, say that the universe is of constant size, and that we ourselves are becoming smaller and smaller. All our surroundings, our metre scales, our atomic standards, even the stars and nebulæ, but not intergalactic distances, share in this diminution of scale. If we do not tamper with fundamental constants such as the velocity of light, our time-scale will also diminish in the same progression. We shall actually vanish. Successive years in terrestrial reckoning are periods diminishing in geometrical progression according to the cosmical time-reckoning, so that an infinite number of years adds up to a finite cosmical time. The lapse of that time puts an end to matter—and to the difficulties to which the occurrence of matter in the cosmos gives rise. But this is at the cost of supposing that " true time " is a function of the cosmos rather than of human consciousness.

Finally, I repeat my personal conviction that the cosmical constant λ is connected with the ratio between electromagnetic and gravitational units, and that sooner or later a theory giving an accurate value of λ will be forthcoming. We shall then have a purely theoretical prediction of the speed of recession of the spiral nebulæ (if undisturbed by mutual gravitation) to compare with astronomical observation. A. S. E.

Nebulæ.

Extra-Galactic Nebulæ.—Since the last note was compiled, in 1929 February, perhaps the most important paper has been one on the " Distribution of Luminosity in Elliptical Nebulæ " by Hubble (*Mt. Wilson Cont.*, 398). These nebulæ show no signs of spiral or structural detail, and range between ellipticities where the major and minor axes are equal, to cases where a lenticular form is presented with a ratio of axes about 3 to 1. The preponderance of round and nearly round images indicates that the actual forms of the nebulæ lie between globular and lenticular, orientated more or less at random in space. There are examples, such as N.G.C. 3115, in which the minor axis is obviously orientated in the line of sight. These show the true lenticular outline and may be taken as the limit of the sequence. As a class their luminosity distribution is remarkably uniform, and they are therefore much more suited to a statistical investigation than the spirals, in which the great difference of structural types of development, coupled with their orientation, makes it impossible to deal with them adequately on statistical lines. Hubble takes the projected outline of the nebulæ for a primary classification, with the idea that luminosity distribution should be brought into the classification later by means of symbols defining the luminosity gradients.

The photographic densities to be measured were obtained by a series of images with graduated exposures of each object, the instrument used being the 100-inch reflector. Transparency curves were

then derived from the images with a Koch registering microphotometer, and combined from the series of images into a single curve. Calibration was effected in the laboratory on plates of the same kind as those used in the telescope, with exposures ranging from 8 seconds to 30 minutes. Hubble finds that the luminosity curves along various axes of the different nebulæ are expressed by a formula of the general form

$$\log I = \log I_0 - 2 \log \left(\frac{r}{a} + 1\right)$$

where I=the luminosity, I_0 the central luminosity, r the distance from the central point of the nebula, and a a parameter varying from nebula to nebula.

An interesting further application of the work is an isophotal contour quadrant of the lenticular nebula N.G.C. 3115. Bearing on this is a paper by J. A. Carroll and E. B. Moss (*M.N.*, **91**, 191) which gives a description of the new registering microphotometer of the Cambridge Solar Physics Observatory. Although, owing to an oversight, the N.G.C. number of the nebula measured with the instrument is not stated, it should be noted that this also is N.G.C. 3115, for which a lenticular form has been derived similar to Hubble's result. The actual linear dimensions of the nebular image obtained with the microphotometer are considerably larger than those which can be seen in a visual microphotometer, owing no doubt to the superior sensitivity of the instrument. The contours also yield outlines of a general lenticular form which is not so apparent to the eye, and it may be hoped that the registering microphotometer will add greatly to the accurate representation of outline and luminosity distribution in the nebulæ.

Two papers by de Sitter based on Hubble's paper on "Extra-galactic Nebulæ" (*Mt. Wilson Cont.*, vol. xiv., No. 324) appear in *Pro. Nat. Acad. Sc.*, vol. xvi., No. 7, and *Bulletin of the Astron. Inst. Netherlands*, vol. v., No. 185. The former is entitled "On the Distances and Radial Velocities of Extra-Galactic Nebulæ" and deals with the explanation of the latter by the relativity theory of "inertia." The latter, "On the Magnitudes, Diameters, and Distances of the Extra-Galactic Nebulæ and their apparent Radial Velocities," contains a discussion of the correlation between the apparent integrated magnitudes and the apparent diameters. In the latter paper a series of formulæ expressing distances are found for the three classes of extra-galactic nebulæ, viz. spiral, elliptical, and irregular. A correlation between radial velocity and distance is then derived. A discussion of the explanation of the large receding velocities of the extra-galactic nebulæ as a class follows, which is based on the inherent expanding tendency of space resulting from the author's solution of Einstein's differential equations for the inertial field. De Sitter comes to the conclusion that a static solution of Einstein's field equations cannot represent the observed facts. He refers, however, to a non-static solution published by Lemaître, in 1927, in *Annales de la Société Scientifique de Bruxelles*, Tome xlvii., where the problem of the radial velocities of the extra-galactic nebulæ is also

dealt with. From this de Sitter finds that the present radius of the universe would be twice its initial value.

De Sitter's other paper is an expansion of that just summarised, especially with regard to Lemaître's work. Some far-reaching conclusions are reached, but there are many difficulties still in the way of a satisfactory theoretical explanation, and Lemaître's work, although very important, cannot be taken as the last word.

The whole of this theoretical structure is based on actual observation of the linear diameters and integrated magnitudes, visual or photographic, of the extra-galactic nebulæ, which are liable to be subject to systematic errors. It is, in fact, a very difficult matter to produce satisfactory statistical data from such a heterogeneous collection of objects as these nebulæ. As de Sitter says, the establishment of a standard scale of diameters and integrated magnitudes is of paramount importance.

In *Nature*, 1930 November 8, p. 722, A. Haas deals with the "expanding universe" hypothesis from the point of view of the disintegration of matter, using Einstein's formula. Letters on this subject also appear in *Nature*, 1930 December 6, pp. 881–82, from W. H. McCrea and Wilhelm Anderson.

In *H.C.O. Bulletin*, 878, Shapley deals with a group of small nebulæ in R.A. $22^h\ 33^m$ and Dec. $+\ 32°\ 52'$. On certain assumptions it is computed that the distance of the system is 16,000,000 light years with an overall diameter of 25,000 light years. The apparent diameters range from 40″ to 110″.

In *A.N.*, 5661, appears a paper by C. D. Perrine, "The Motions and Status of the Spiral Nebulæ and Clusters." A certain degree of correlation is found to exist between radial velocity and galactic latitude, as well as between size and apparent ellipticity. The conclusion is reached that "the spiral nebulæ have not been feeders of the galactic system, but on the contrary the galactic system has furnished the material or energy from which these bodies have been built up."

Galactic Nebulæ.—The late Dr. Hagen of the Vatican Observatory devoted much attention to the "dark" nebulæ of Herschel, some of which are well-known galactic objects. He found these to be slightly luminous by visual observation at the telescope, but no photographs yet exposed on many of the areas in which they were said to occur have yielded any perceptible darkening of the film.

An instance of this is afforded by Hagen's paper in *M.N.*, **90**, 331, 1930, "On the Significance of Baxendell's Nebulosity," observed visually with a 5-inch refractor as being "closely attached to the bright globular cluster M2." Photographs of the region were taken with orthochromatic and panchromatic plates at various observatories, and all of them failed to show the nebulosity. Dr. Hagen took up the position that visual observations were so well determined that the fault lay with the photography, and he elsewhere suggested that possibly the correct developer had not been discovered which would bring out the latent image.

Two papers appear in *A.N.* dealing with this subject. In No. 5706

Dr. Hopmann suggests that fixed sodium lines are to be found in spectra of certain stars, and there is a possibility that clouds of sodium yielding a faint yellow light are present in particular regions. Faint yellow light is difficult to photograph owing to the contrast factor being greater in panchromatic plates for this part of the spectrum than that for blue and ultra-violet light, and Hopmann suggests that this is the reason why the objects yield no positive photographic results. He thinks that a definite test could be applied with special short-focus lenses and colour screens, and he proposes to carry out the work in the Argentine.

In *A.N.*, 5702, Osthoff contributes a paper, "Die Farbung der Hagenschen Dunkelwolken." This gives examples of galactic nebulæ where inconsistent results as regards brightness and visibility have been obtained with the various types of instruments employed by different observers. He also suggests that reddish colouring of the nebulæ makes it difficult to obtain photographic images.

"Visual Observations of Dark Nebulæ" (*M.N.*, **90**, 326, 1930, by W. S. Franks) deals with a survey of Barnard's list which appears as Part II. of his *Photographic Atlas of the Milky Way*. The "dark" nebulæ were observed visually with a 6-inch refractor. In the same volume, p. 226, appears a note on a dark nebulosity in the region of Nova 2 Geminorum, by T. E. Espin, who confirms a suggestion made previously by Dr. Steavenson.

Dr. W. J. S. Lockyer also contributes a paper to the same volume on "Monochromatic Images of the Orion Nebula" (p. 580). The nebula was mapped out into specific regions under certain letters, and an arbitrary scale of densities was adopted for particular portions of the images in the various wave-lengths. As the instrument used was the 9-inch prismatic camera, with a dispersion of 46 mm. between $H\beta$ and $H\delta$, there is very little overlapping of images. At the same time only the central regions of the nebula are to be seen in the reproductions of the spectrograms, and for details of spectral distribution in the outer regions it is necessary to refer to photographs exposed with colour screens transmitting a limited range of spectrum. Perhaps the principal distinction found between the two methods is the difference in brightness of $\lambda\lambda$ 3727/9. In the screened negatives this radiation is by far the strongest of all in the outer regions and is quite conspicuous in the Huyghenian region. In Lockyer's results it appears as the faintest of the principal emissions; this must obviously be put down to the reduced transparency of the optical system for ultra-violet rays. There can be no doubt that the unscreened images produced by exposures on ordinary plates with a reflector consist largely of $\lambda\lambda$ 3727/9.

J. H. R.

List of Public Institutions and of Persons who have contributed to the Library, etc., since the last Anniversary.

(*Institutions exchanging publications with the R.A.S. Library are omitted from the list, in order to economise in printing.*)

American Association of Variable Star Observers.
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Paris, Comité international des Poids et Mesures.
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Prague, Sternwarte der deutschen Universität.
Rome, Società Italiana della Scienze.
Rome, Società Italiana per il Progresso delle Scienze.
Science Service.
Swedenborg Society.
Tachkent, Astronomical Observatory.

Tachkent, Université de l'Asie Centrale.
Tokyo, National Research Council of Japan.
Tokyo, Physico-Mathematical Society of Japan.
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ADDRESS

Delivered by the President, Dr. A. C. D. Crommelin, on the award of the Gold Medal of the Society to Professor Willem de Sitter, for his theoretical investigations on the orbits of the satellites of Jupiter, and for his contributions to the Theory of Relativity.

For the second time in three years the satellites of Jupiter form the chief subject-matter in the award of the Gold Medal. Professors Sampson and de Sitter have both devoted a great number of years to the study of their motions. Readers of the *Observatory* may remember some animated discussions between them in the early years of this century in the pages of that periodical. Such discussions between experts are likely to be most useful, and have often been the means of leading to the detection of errors, or to the suggestion of new points needing examination. In the present case Professor de Sitter acknowledged that the discussion had led him to see that some tables of Mr. Marth's, which he had relied on as sufficiently accurate for his purpose, did not completely correct the major axes of the orbits of the satellites for the effect of their mutual perturbations.

Professor de Sitter's astronomical career began in the Astronomical Laboratory at Gröningen, of which Professor J. C. Kapteyn was Director. In a letter that he wrote to Sir David Gill, which is published in the *History of the Cape Observatory*, p. 87, de Sitter tells us that even after he went to Groningen he did not contemplate becoming a professional astronomer, but intended to become a mathematician. We owe to Sir David Gill the call to the career in which he has done so much useful work. The circumstances of de Sitter's introduction to the system of Jupiter are sufficiently interesting to tell at some length.

Sir David Gill, on becoming Director of the Cape Observatory in 1879, had a discussion with Professor J. C. Adams on the observations that were needed to improve our knowledge of the Jovian satellite system. Adams replied that up to that time reliance had chiefly been placed on the observation of eclipses of the satellites; these gave fairly good determinations of their longitudes, but were of very little value for the latitudes. The latter needed observations in order to obtain improved values of the inclinations and nodes; Adams suggested observing the latitudes of the shadows when crossing the disc; but this involved placing a thread tangential to the limb of Jupiter, an operation that Gill knew to be liable to systematic error; he conceived the idea of comparing one satellite with another by measures of distance and position angle with the heliometer. Successful work on stellar parallax had been accomplished with the 4-inch heliometer, leading to the procuring of a larger one, with an aperture of 7 inches. This was first devoted to a determination of the solar parallax from observations of Iris, Victoria, and Sappho. Triangulation of the comparison stars was incidental to this programme, and, as they were also observed on the

meridian at many observatories, their positions were known with extreme accuracy. They could thus be used afterwards for testing the heliometer scale ; an accuracy of 1 part in 100,000 was found to be attainable ; such an accuracy was called for if useful work was to be done in improving the determination of the mass of Jupiter, as the probable error of Newcomb's mass was only 1 in 26,000.

The heliometer observations were made by Gill and Finlay in the closing months of 1891, but their reduction and discussion were postponed. Gill visited the Gröningen Laboratory in October 1896, where he made the acquaintance of our medallist, and eventually invited him to come to the Cape Observatory and give assistance in some of the investigations that were awaiting discussion. De Sitter asked to be allowed to defer the visit till the following year, to enable him to pass the preparatory examinations for the doctor's degree. He arrived at the Cape in August 1897, and remained there for $2\frac{1}{4}$ years. His observational work consisted of a photometric programme in connection with an investigation initiated by Professor Kapteyn ; we shall revert to that later. He also did some parallax and triangulation work with the heliometer ; but his main interest lay in the discussion of the Jupiter observations. He took great pains to free the results from systematic errors. The polar triangulation with the heliometer had revealed an error in measures of distance with that instrument, varying as the square of the distance ; but good reasons were found for believing that this error was not present in the Jupiter series. He was strict in excluding all observations in which conjectural alterations had been made to the original readings. The series of observations was too short to permit of determining the masses of the satellites. These were, however, studied later, using other series of observations. For the mass of Jupiter, de Sitter found from the 1891 observations alone 1/1047·50, with a probable error of $\pm$ ·06 in the denominator. Two other determinations, made by Mr. Bryan Cookson at the Cape in 1901 and 1902, also by the heliometer, had given 1047·46 and 1047·25, with somewhat larger probable errors, owing to the smaller numbers of observations. Combining these with the material used by Newcomb, excluding, however, results depending on comets, and on old heliometer observations of the satellites (made without a check on the scale-value), de Sitter gave as the definitive mass of the Jovian system 1/1047·40 $\pm$ ·03. For the planet alone, without the satellites, the denominator becomes 1047·60.

I should like to interpolate here the hope that a new value of Jupiter's mass may be derived from the eighth satellite. Jupiter has now almost completed two revolutions since its discovery in 1908. Unfortunately observations of the satellite were discontinued after 1923 ; but, thanks to an ephemeris computed by Professor Numerov, numerous observations of it have been obtained in the last two months at Mount Wilson and Yerkes.

I remember that, after the satellite was discovered, Sir David Gill expressed his expectation that it would lead to an improved determination of Jupiter's mass. The huge major axis of the satellite's orbit

should more than compensate for any slight inferiority in the accuracy of the positions.

The above research is given in full in vol. xii. of the *Cape Annals* (1914). A pathetic interest attaches to it, since the Introduction to it was the last work on which Sir David Gill was engaged. His last illness came on before it was completed, and it was finished by de Sitter. It is followed by a discussion of the inclinations and nodes of the satellite orbits. In this de Sitter made use of provisional values of the masses which he had deduced in *Gröningen Publication*, No. 17, 1907; that publication is a study of the librations of the first three satellites about the position of equilibrium given by the equation $l_1 - 3l_2 + 2l_3 = 180°$. The librations are so small that the investigation is difficult; the period was at first thought to be 7 years, but this was afterwards reduced to 6 years; the masses found from the 7-year assumption practically agree with the final ones for satellites II. and III., but that of I. is only two-thirds of the final one. The mass of I. is evidently by far the most difficult to find, as Laplace and Damoiseau, while giving fairly correct values for II., III., and IV., give I. a mass less than half its true value. The values finally adopted for I. by de Sitter and Sampson are in the ratio of 5 to 6, while those of II., III., IV. in no case differ by more than 1 in 40. We can understand the difficulty for I. by remembering that, since it is inside the orbits of the others, its action is more or less entangled with that of Jupiter itself. Sampson's period for the libration is 5 years 7 months; the libration is so small that it can only be detected by most exact observations and analysis. Keeping the relative motions of I., II., III. unchanged there are five possible symmetrical arrangements for the satellites besides the actual one; de Sitter showed (*Proceedings of Amsterdam Academy*, **11**, 682, 1909) that three of these are certainly unstable; the other two also appear to be unstable with the actual values of the elements.

The masses are of such fundamental importance in the theory that I thought it well to make a tabular statement of the values adopted at different times. They are expressed in units of the eighth decimal of the mass of Jupiter.

Sat.	Delambre.	de Sitter (provisional).	Sampson.	de Sitter. (final).
I.	1700	2610	4497	3796
II.	2300	2310	2536	2477
III.	8800	8040	7988	8201
IV.	4248	4250	4504	4523

Damoiseau professed to use Delambre's masses, but his coefficient of the principal inequality of III. due to IV. implied a mass of IV. equal to 2149. J. C. Adams still used this mass in his continuation of Damoiseau's tables. It is curious that de Sitter was led to the value 2230 for IV. in a discussion of some old observations of eclipses of III. (*B.A.N.*, No. 4, 1922). Its agreement with the value used by Adams made him think for a time that it might be right, but he was eventually convinced that the large value is the true one.

I thought it of interest to compare the masses and densities of the satellites with those of the Moon ; de Sitter's masses (Moon = 1) are 0·99, 0·64, 2·13, and 1·17 ; the densities come out (Moon = 1) 1·06, 1·00, 0·61, and 0·38. Sampson's figures are almost the same except for I., in which his values give mass 1·17, density 1·25. There is a faint resemblance in the arrangement to that of the planetary system, the bodies nearer to the primary having smaller masses and higher densities. The density of IV. is about the same as that of Jupiter.

To return to the discussion of the nodes and inclinations ; besides the series of heliometer observations in 1891, 1901, 1902, a photographic study of the satellites was made in 1903 and 1904. The orientation was determined by trails of Jupiter, but the planet was not otherwise used for measurement. Some standard stars were photographed for scale-value. The determination of the rate of change of the different elements was made first from the Cape observations alone, and secondly by comparison with the values for 1750, as given by Delambre.

The theoretical discussion of the above material, to which series of photographic observations made at the Cape, Johannesburg, Greenwich, Leiden, Pulkovo, and the Yale station in South Africa were subsequently added, is contained in the *Annals of Leiden Observatory*, vols. xii. and xvi. The first section of this appeared in 1918. The introduction explains the use of an intermediary orbit in which the eccentricities are taken as zero, and the great inequalities appear as equations of the centre ; this "for the three inner satellites is a better approximation to the true motion than the undisturbed Keplerian ellipse." This orbit contains the principal terms of the periodic solution ; we are reminded of the similar use of the Variation Oval in recent work on the lunar theory. It has the advantage in the present case of doing away with the trouble arising from small divisors. The adopted mean motions are derived by comparing Damoiseau's values for 1750 (after applying some corrections to them due to wrong light-time having been used, etc.) with modern observations ; very small corrections were applied, to cause the relation between the motions of I., II., III. to be exactly fulfilled. The intermediary orbit adopts the plane of Jupiter's equator as the plane of reference, thus simplifying the application of perturbations arising from Jupiter's figure, but of course at the cost of making the application of the solar perturbations a little more troublesome. As illustrating the extreme care that our Medallist took to include everything that could have an appreciable effect, I refer to a paper that he published in the *Proceedings* of the Amsterdam Academy for 1915 ; he pointed out that the shorter rotation period of the equatorial zone of Jupiter would produce a narrow protuberance beyond the elliptical outline, extending for some 7° of latitude on each side of the equator. Its height, as seen from the earth, was found to be less than 0″·01, and its effect on the time of an eclipse of satellite IV. about $\frac{1}{14}$ of a second. The gravitational effects of this protuberance on the satellites were found to be inappreciable.

The second and third sections of the discussion were published in 1919 and 1925 ; the second has Dr. A. J. Leckie's name as author, but

it was carried out in connection with Professor de Sitter's investigation. These two sections contain the numerical development of the perturbations. In the expansion of some of the larger quantities, which contain a great number of terms, a few terms have been added at the end, deduced by extrapolation ; the law of progression of the terms has been examined, so the extrapolated terms cannot be much in error ; indeed they are so small that their neglect would not have led to serious error. A very large number of terms of the third degree were investigated, but very few were of sensible magnitude ; this could not, however, have been inferred with certainty beforehand.

The coefficient of the largest term in longitude is about $1\frac{1}{2}'$ for satellite I., 3′ for II., 10′ for III., 51′ for IV.

Before finally adopting the elements of the different satellites, de Sitter made a careful re-reduction of a great number of observed eclipses, which go back to 1668, and include the well-known photometric series made at Harvard between 1878 and 1903, also a recent series at Johannesburg. The systematic errors of the different observatories are deduced (observations as a rule not being kept unless there is sufficient material for deducing them). The discussion is published in *Leiden Annals*, vol. xvi., Nos. 2 and 4 (1928, 1929). No. 2 includes a discussion of the correction from astronomical to Newtonian time due to the secular retardation of the earth's rotation and the fluctuations in that rotation. Our Medallist was not the first to notice the desirability (we might almost say the necessity) of considering this correction in discussing series of observations that extend over long periods, but he has done much work in seeking for the curve that best fits the results of lunar, solar, planetary, and satellite observations. The *Transactions* of the Leiden Meeting of the Astronomical Union (1928) contain a formula on p. 41 which our Medallist proposes for adoption ; it consists of two parts : (1) a correction of parabolic form arising from a uniform retardation of rotation ; (2) a correction the graph of which is a zigzag of straight lines of varying slope ; the dates of seven abrupt discontinuities in the slope are given, the earliest being 1664·0, and the latest 1918·65. A graph of the resultant curve is published in *Leiden Annals*, xvi., No. 2, p. 79, 1928. The results from eclipses of Jupiter's satellites are in fair agreement with it, except the first group, the mean date of which is 1710. Incidentally, if de Sitter's time correction is used for the moon, Brown's great empirical term must be omitted ; a formula is given for the term needed to take its place.

The only change actually adopted in the elements previously obtained for Jupiter's satellites, as a result of the new discussion of the old eclipses, is an improved value for the motion of the node of III. The other corrections found are not larger than the uncertainty of their determination ; the discussion shows that this uncertainty is larger than was expected, and that time determinations from eclipses of the satellites are uncertain by at least ten seconds either way.

The new theory of the satellites is not yet reduced to the form of tables, but the preparatory work appears to be complete, so we may hope that the appearance of tables is not very distant. There is rather a

curious parallel between the moon and Jupiter's satellites in the matter of tables ; after the long period of sixty years, during which Hansen's lunar tables were in sole possession, those of Brown and Radau appeared nearly simultaneously. Damoiseau's tables of the satellites were in possession of the field for a still longer period, having been published in Paris in 1836. After this long comparatively blank period, two researches were carried out almost simultaneously by our Medallists of 1928 and 1931, both of which represented an enormous advance over Damoiseau ; both of them involved intricate calculations, needing most careful treatment ; they will provide much firmer stepping-stones to the theorist who essays, in the remote future, to make a still further advance.

It is right in this place to refer to another man who made a notable advance in the theory of the satellites. This is M. Souillart, whose theory appeared in 1880, in vol. xlv. of the *Memoirs* of this Society. Both our Medallists pay a tribute to the value of his work, which has been of use to them in their researches. But it was never reduced to the form of tables, so that the predictions in the ephemerides did not derive any benefit from it.

In reviewing other work of our Medallist, I will begin with the research in which he was engaged at the Gröningen Laboratory at the time when Gill met him there and invited him to the Cape. *Publications* 2 and 3 of that laboratory are in his name, and were written before his departure to the Cape in 1897. Kapteyn had found in 1890 that the C.P.D. contained more stars than the other southern Durchmusterungs in low galactic latitudes, but fewer in high latitudes. It was seen that this might arise either from the galactic stars being bluer than the extra-galactic or from the crowding of stars in the galaxy, rendering the visual surveys less complete than in the sparser regions. In the hope of settling the matter, some photographs were taken at the Cape in 1893 and 1894 ; these were discussed by de Sitter, who concluded that there was a real difference between photographic and visual magnitudes, depending on galactic latitude ; he also found that the so-called isochromatic plates of that date were only very slightly more efficient for red stars than the ordinary plates. He utilised his visit to the Cape to investigate the question further. New plates were taken in which the exposure was only ten minutes instead of twenty, and the visual magnitudes were doubly observed ; by himself, using a Zollner photometer that he had brought out for the purpose, and by Dr. Innes using the method of eye estimation. Once more the conclusion emerged that in all the visual Durchmusterungs the magnitudes of galactic stars are estimated as two- or three-tenths of a magnitude fainter than near its poles. Various possible causes are discussed ; the effect on visual observers of the crowded fields and luminous background in the galaxy, and possibly the rendering of the photographic plates more sensitive in the galaxy by the effect of exposure to this luminous background. It is noted that the difference did not appear in Dr. Innes's measures ; he was simply observing selected stars in the galaxy, not attempting to record them all ; this suggests that we can

ascribe the effect to the greater haste that was necessary in attempting to record all the stars in a crowded field. But de Sitter noticed further that the colours of the galactic stars were less homogeneous than those of the non-galactic ones. He suggested that the presence of absorbing matter in large regions of the galaxy might account for this. Recent results from the American observatories have tended strongly in the same direction. The above research is published in No. 12 of Gröningen Laboratory *Publications*, 1904.

Another line of work to which our Medallist has contributed important results is that relating to the improvement of the numerical values of the elements of the solar system. I have already mentioned his study of the variable rotation of the earth, which was suggested to explain the irregularities of the moon's motion, and was supported by study of the other bodies with rapid motion : I give some more details of this investigation, which is in *B.A.N.*, vol. iv., 1927. One question which troubled the early investigators was whether they should try to explain the whole departure of the moon from theory by variable rotation, or should restrict that explanation to the smaller oscillations that remained after the great empirical term had been applied. While on the subject of this great empirical term, I think it is of interest to sketch its history.

Hansen's tables contained, besides the genuine large Venus term, a second so-called Venus term, the coefficient of which was not calculated, but was adjusted to give the best fit with the lunar observations of the preceding century ; calculation has subsequently shown that the coefficient of this term is quite insensible, so that it was really an empirical term. Hansen's tables began to go wrong after a few years. Newcomb's well-known researches led him to suspect the accuracy of this Venus term ; Newcomb's corrections consisted in altering the longitude at Epoch, the mean motion, and the acceleration, and also in substituting one empirical term for another. On the whole, Newcomb was a little nearer pure theory than Hansen was, so that all the outcry against Newcomb's corrections, as though they introduced empiricism into the lunar tables for the first time, was quite unjustified. Newcomb's term had the advantage over Hansen's that it represented a considerably longer period than the other.

It was found that the moon continued to deviate from the tables, even after Newcomb's corrections had been applied. Various attempts were made to represent these deviations by sine-curves ; I think the latest attempt was the one by the Astronomer Royal and myself in *M.N.* for 1923 April ; we gave two terms, with periods 70 and 59 years respectively ; we are not much surprised to find that the moon has not conformed closely to our prediction in the seven years since it was made. It is unlikely that any further attempts of the kind will be made, as Professor de Sitter has shown that the deviations are represented more closely by a zigzag of straight lines than by sine-curves ; this suggests that they arise from abrupt changes in the arrangement of matter in the earth's interior, which take place at irregular intervals. He examined the times of contact in all the recorded

transits of Mercury, and found that they gave a curve of residuals very similar to that of the large empirical term for the moon; he concludes that this term, like the terms of shorter period, arises from changes in the earth's rotation; it will probably be discarded in the future.

De Sitter makes another suggestion to explain some of the oscillations of long period in the moon. Dr. Jeffreys and others showed that the main tidal retardation occurs in semi-landlocked seas like Behring Sea. Now these may undergo sensible changes in the course of centuries, such as the silting up or the deepening of channels. This would affect the tidal retardation, and also the real rate of motion of the moon.

He also pointed out that, since the moment of momentum of the earth-moon system remains constant, any change in the earth's rate of rotation must be accompanied either by a change in the earth's moment of inertia, or in the angular momentum of the moon, or in both. His discussion tends to the conclusion that the moon is itself affected, and that in consequence the apparent change of rate of other bodies bears a higher ratio to their mean motion than in the case of the moon. He finds that they are greater in the ratio 1·25 : Jupiter's satellites gave the higher ratio, 2·62, suggesting the possibility that the Jovian system may have fluctuations of its own, arising from changes in Jupiter's rate of rotation (*B.A.N.*, **4**, 38, 1927).

Another important paper by de Sitter, in vol. iv. of the *B.A.N.*, 1927, discusses the most probable values of various important constants; he refers with admiration to Newcomb's *Fundamental Constants of Astronomy*, published in 1895; but the great number of observations made since then allows improvements to be made. I quote some of the suggested values. Mean radius of the earth, 6371·24 km. Acceleration of gravity at mean latitude, 979·77 cm. Precession (all sources), 50″·2486. Nutation, 9″·208. Solar parallax, 8″·803. Lunar parallax, 3422″·52. Compression of earth, 1/296·96. Mass of moon, 1/81·53. Hinks's value for the last named is retained, pending the results that will be obtained from the present apparition of Eros. It is very useful to have a list of mutually consistent constants, selected by an authority of so much experience and judgment as our Medallist.

In the discussion of the figure of the earth, an examination was also made of the distribution of density in its interior. Wiechert's hypothesis of a core and crust, each of constant density, was found to be tenable, but to lead to several possible solutions, two of which were worked out. The first gave the radius of the core 5208 km., outer density 2·760, inner density 7·816; the second gave 4906 km., densities 3·312, 8·187.

I pass now to the contributions to the theory of relativity made by our Medallist. Einstein published in 1905 his restricted principle of relativity, which asserted that it is impossible by any conceivable experiment to detect uniform motion through the ether. Even this restricted principle attracted much attention. Our Medallist contributed a long paper to *M.N.*, **71**, 388 (1911 March), investigating the

slight variations from Newtonian dynamics that it would produce. The only one that was large enough to be of interest was the motion of the planetary perihelia; the theory gave centennial motions of 7″·2, 1″·4, 0″·6, 0″·2 for Mercury, Venus, Earth, and Mars respectively. This result had been already published by Professor Lorentz and Mr. Wacker; the motions are proportional to those given by the later theory, but are smaller in the ratio of one to six. Even in the earlier theory the suggestion was made that there might be some deflection of light by gravitation; preparations were made to test the suggestion at the eclipse of 1914 August; but the outbreak of war rendered the attempt abortive. In 1915 Einstein published his general theory of relativity; its main point of difference from the former theory was that it included gravitation; it laid down that "a gravitational field of force at any point of space is in every way equivalent to an artificial field of force resulting from acceleration, so that no experiment can possibly distinguish between them." Most of us first learnt of the new development in a paper by our Medallist in *M.N.*, **76**, 699 (1916). This was followed by two others, *M.N.*, **77**, 155 (1917), and **78**, 3 (1917). The first paper introduces us to the four-dimensional time-space continuum, and lays down as a postulate "that the laws of nature are to be invariant for all transformations of co-ordinates." A mathematical discussion follows, leading up to the three astronomical tests: (1) the bending of light by the sun, the amount being twice as great as that of a particle moving with the speed of light under the Newtonian law; (2) the spectral shift towards the red in a gravitational field; (3) the shift of perihelia is six times as large as it was under the restricted theory, and exactly agrees with the observed shift in the case of Mercury, the only planet for which the difference between the old and new is appreciable; it was this last test that carried almost immediate conviction of the truth of the new law to many astronomers; for the agreement was undesigned; the law was formulated before it was known what value would result for the shift.

It was seen that the first test was a very promising one for affording further corroboration; and that the eclipse of 1919 May had an excellent field of bright stars. Tentative arrangements were at once made for observing it, if the war ended in time; this was fortunately the case. I may be allowed to add a personal note; owing to the absence of many of the staff on war service, I had the good fortune to be selected as an observer of this eclipse; there was the double satisfaction of having a share in a very important astronomical test, and of realising a life-long desire of seeing the southern heavens. The observations of that eclipse and of the one of 1922 are generally admitted to have established the Einstein shift.

The test of the spectral shift was not fully confirmed till 1925, but even in 1916 de Sitter pointed out that on the average the lines in stellar spectra were shifted towards the red; in fact in the B stars the shift was three times too large.

De Sitter goes on to sketch the effect of the theory on the dynamics of the solar system; he notes that it produces small corrections to the

motion of the lunar perigee and node. We come to his first disagreement with Einstein, when he criticises his postulated huge masses at infinity. Indeed, Einstein himself saw the weakness of this assumption, and put forward another, in which the world-matter was supposed to be distributed through the whole of his finite space ; in fact it no longer differed essentially from the matter that comes within our cognisance. This solution requires the introduction of a new term " Lambda," which is the curvature of the four-dimensional space-time if there were no matter. De Sitter's third paper examines three different ideal worlds ; the first (system A) is Einstein's revised world which has just been mentioned ; the second (system B) has since become known as de Sitter's world ; it agrees with the first in giving space-time a positive curvature, but it simplifies the conditions by imagining the absence of matter ; the positive curvature implies that space is not of infinite extent, but re-enters on itself ; the third (system C) is also without matter, and, moreover, the quantity " Lambda " is assumed to be zero, so that three-dimensional space is euclidian ; this would be the ordinary space as conceived in pre-relativity days, so that it does not need further discussion from a relativist point of view. The paper goes on to discuss the question of rays of light passing right round the " world," this word being used to denote the whole of space ; this is a question which was the occasion of discussion twelve years ago, but which has ceased to be of much practical interest ; we may note, however, that de Sitter stated that the time required for the light-journey would be finite in system A, but infinite in system B.

The next point is of greater present interest ; I quote some words from de Sitter's paper (*M.N.*, 1917 Nov.) : " In the system B . . . the frequency of light-vibrations diminishes with increasing distance from the origin of co-ordinates. The lines in the spectra of very distant stars or nebulæ must therefore be systematically displaced towards the red, giving rise to a spurious positive radial velocity." He then refers to the K-term for the B stars, which indicates a recessional velocity of $4\frac{1}{2}$ km./sec. ; he has already ascribed $1\frac{1}{2}$ km./sec. to the gravitational shift ; the remainder, or part of it, may be put down to the other cause. The spiral nebulæ supplied a more hopeful test of the theory ; in 1917 there were only three radial velocities of these that had been determined by more than one observer ; the Andromeda nebula gave a velocity of approach of 311 km./sec., N.G.C. 1068 and 4594 gave recessions of 925 and 1185 respectively. Professor Slipher was a pioneer in these measures.

According to the latest determination the sun's motion, including galactic rotation, is carrying it towards a point that is only 36° distant from the Andromeda nebula, with a speed of 286 km./sec., which would account for most of the speed of approach. Our knowledge of the radial velocities of the spirals has been greatly increased since 1917, through the work of Dr. E. P. Hubble and other members of the Mount Wilson staff ; more than fifty of these velocities have now been measured, and the measures have been extended to the fainter and smaller nebulæ, which are presumably the more distant ones. At the

beginning of 1929 the largest recessional velocity was 1800 km./sec.; since that date velocities of 4000, 7000, 8000, and quite recently one of 11,500 (by Mr. Humason) have been announced; a correlation of speed with diameter and brightness was made some time ago by the Mt. Wilson observers; Professor de Sitter has made an independent study of it in *B.A.N.*, **5**, 157 (1930 May). He first studies the correlation between magnitude and diameter of the spirals, finding this to be very close. He proceeds to estimate the distances from the combination of magnitudes and diameters, and finally correlates distance with radial velocity; he draws the graph as a straight line, which indicates a recession of 144 km./sec. for a distance of one million light-years,* and proportionally for other distances. Naturally there is a good deal of scattering, due chiefly to the uncertainty in the distances, but also to the individual motions of the spirals. The effect of the sun's motion has been taken out; this being assumed as 286 km./sec. towards R.A. 314°, N.Decl. 66° (Strömberg).

Once the proportionality of spectral shift to distance has been established, it is clear that this gives a very good means of obtaining the distances of the spirals. It actually becomes better the greater the distance, since the individual motions are likely to bear a smaller proportion to the total shift when this is large. Thus for the second time the spectroscope becomes available as a measurer of distances, the first time being the introduction of the method of spectroscopic parallaxes for stars in our own galaxy.

The determination of the distances of the spirals would be equally valid whether the spectral shifts are spurious, arising from the properties of the space-time continuum, or whether the recessions are real. De Sitter used the word *spurious* in his 1917 paper, but he now considers the expansion of the system of galaxies as real. He makes acknowledgment to a paper by Abbé G. Lemaître (*Annales de la Société Scientifique de Bruxelles*, 1927 April), which was described by Sir Arthur Eddington in *M.N.*, **90**, 668 (1930 May). This paper made it evident that the Einstein world is unstable, so that the smallest disturbance would start expansion or contraction; evidently expansion is the case in the actual world. It will be remembered that the de Sitter world was defined as being without matter; obviously that was not meant to be taken *au pied de la lettre*, and the question arises, "Is the actual world empty enough to satisfy the conditions?" De Sitter answers this as follows (*Scientia*, 1931 January): "The universe is many billions of times as empty as our most perfect vacuum. . . . But this is not the way in which we must measure the emptiness. We must use as a standard . . . the theoretical density of the static universe. . . . This comes out only about ten times that found above. . . . The actual universe is thus very far from empty; it is, on the contrary, nearly full." He goes on to say that the static and the empty universe are the only possible equilibrium solutions, and that the actual universe is not in equilibrium.

* It may be pointed out that de Sitter's unit of distance A is 10^{24} cm., or 1,057,000 light-years.

De Sitter goes on to endeavour to trace the past history of the world ; we have to go back only a few thousand millions of years to find the mutual distances less than half their present values. If, as de Sitter thinks likely, the expansion is effective for the interstellar distances within each galaxy, not only for the intergalactic distances, then our own galaxy was more condensed then than it is now ; this would increase the probability of close stellar appulses, such as it is now usual to invoke to explain the origin of the planetary system. Most cosmogonists now demand periods of millions of millions of years for the past history of the stars. De Sitter makes two suggestions that would permit of such a duration. The first is that the initial state was one of extreme compression ; the distances then being small, the expansion would be slow, so that the compressed state would be of long duration. The other suggestion is that there was a period of contraction before the present period of expansion, the minimum size being reached a few thousands of millions of years ago. No reason is given for the change from contraction to expansion ; unless some cause can be assigned the change does not appear to be very probable.

De Sitter's estimate of the present radius of the world is two thousand million light-years, which is about fourteen times the estimated distance of the most distant nebulæ now photographed at Mount Wilson ; he estimates that it may contain eighty thousand million galaxies. The total mass can be obtained independently of this estimate ; both he and Eddington make it of the order of 10^{55} grams. He notes that an electron bears about the same proportion to a pin-head that the pin-head does to the sun or the sun to the galactic system ; the ratio of diameters in each case is of the order of 1 to 10^{12}. But the ratio of the diameter of the galaxy to the diameter of space is much larger, say, 1 to 40,000 ; thus the tightness with which galaxies are packed in space is much greater than that with which protons and electrons are packed in stars, or even in the pin-head, or than stars are packed in each galaxy. This tight packing will not be affected by the expansion of the world, if the individual galaxies also expand in the same ratio.

As regards the solar system, he points out that its linear dimensions would have doubled in the period usually assigned for its past duration ; but that other influences (resisting medium or tidal forces) would have a comparable, or even a greater, effect (*B.A.N.*, **6**, 276, 1930).

Professor de Sitter has also taken an interest in the determination of the positions of the fundamental stars. He realised the difficulty of obtaining accurate declinations from meridian observations owing to the uncertainties of instrumental flexure, and to a less degree of refraction. He suggested the observation of stars in azimuth from a station near the equator, thus eliminating uncertainties in the vertical direction. Observations of this kind were made by C. Sanders and J. H. Oort at a station in Portuguese Congo, in latitude 5° South (*B.A.N.*, **2**, 201, 1925). They indicate a correction to Boss's declinations near the equator of $-0''{\cdot}53$, in good agreement with the value $-0''{\cdot}56$ found by Mr. Roy. The International Astronomical Union, at the meeting in 1925, were so convinced of the value of this work that they voted to

Professor de Sitter a grant of £250 per annum for three years, to assist its further prosecution.

Unquestionably we must assign to Professor de Sitter a large part of the credit for the valuable work that has been carried out at the Leiden Observatory, though we recognise how well he has been supported by a most competent staff; it will suffice to mention Professor Hertzsprung, who was our Medallist two years ago, and Dr. J. H. Oort, who made a notable contribution to the theory of galactic rotation. The hospitality offered by the Union Observatory, Johannesburg, to an observer from Leiden resulted in a valuable catalogue of southern double stars by Mr. van den Bos. The system is still in operation, Mr. van Gent being now at Johannesburg.

The kind hospitality that Leiden offered to the International Astronomical Union in 1928, when Professor de Sitter was its President, will be fresh in the memory of many Fellows of this Society.

The President, addressing the Netherlands Minister, said:—I beg to thank your Excellency for honouring the Royal Astronomical Society by your presence to-day in order to represent the distinguished Director of the Leiden Observatory, and to receive the medal on his behalf.

In handing it to you for conveyance to Professor Willem de Sitter, I beg you to assure him of our appreciation of his persevering labours on difficult problems of dynamical astronomy and of relativity. We regard the results that he has already obtained as of great value, and we hope that he may enjoy many more years of useful work; and that he may derive some encouragement from the evidence which we desire to convey by this award of the high esteem in which he is held by the Society.

Address on the Award of the Jackson-Gwilt Medal to Mr. Clyde W. Tombaugh for the Discovery of the Trans-Neptunian Planet Pluto.

The terms of the award of the Jackson-Gwilt medal are defined as follows: "It may be given for the writing of an astronomical work or memoir, the invention or improvement of an astronomical instrument, the discovery of a new heavenly body, or the promotion in any other way of the science of astronomy." We may be sure that the donor would have most cordially approved of the present award of her medal for a discovery which has nearly doubled the area of the known planetary system, and has extended the distance to which known planets recede from the sun from thirty units to fifty. There is a further note of fitness in the fact that this medal bears on its obverse the portrait of Sir William Herschel, who was the first since prehistoric times to add a new member to the list of known planets. In this connection I would recall that the late Professor Percival Lowell was born on March 13, the anniversary of the discovery of Uranus in 1781, and that the double

anniversary was deemed to be an appropriate occasion for announcing the discovery of Pluto to the astronomical world.

Our medallist was engaged till two years ago in work on the land; but even at that time his thoughts and aspirations were centred on celestial fields more than on terrestrial ones. With the help of instructions that were published in the *Scientific American* he constructed several reflecting telescopes, and he states that the latest of these gave satisfactory views of the moon and planets. But he was anxious for a more definitely astronomical career than was possible in his short hours of leisure; he wrote to Professor Slipher, asking whether any employment could be given to him at the Lowell Observatory. To his joy his request was acceded to, and he was one of those who took photographs with the newly acquired Lawrence Lowell camera, so called because it had been presented to the observatory by the brother of the late Percival Lowell. It was made by the late Rev. Joel Metcalf, well known for his discoveries of comets and minor planets. It has a triplet objective of 13 inches aperture. Professor Slipher states that it was specially designed to search for the trans-Neptunian, Dr. Metcalf being a firm believer in Lowell's prediction. It has, in fact, proved most efficient for that purpose. After the discovery we learnt that the search for the body predicted by Lowell had been kept up at Flagstaff ever since his death, in accordance with directions left in his will. We now know that his prediction of the probable brightness of the planet was two or three magnitudes in excess of the reality; in consequence, exposures had been given with lenses of smaller light-grasp, that were inadequate to record objects of the fifteenth magnitude.

Mr. Tombaugh had been taking photographs with this camera for about six months when at last on 1930 January 21 a plate was exposed that contained an image of Pluto. But, of course, it could not be distinguished from a star till a second plate was available; this was obtained two days later, and the two were compared, with the blink comparator; a shift was detected of just the amount to be expected in a trans-Neptunian body near opposition. I quote a few words from an article by the New York Correspondent of the *Morning Post*, published in its issue of 1930 March 15. "Young Tombaugh admits he was wonderfully thrilled by the discovery, saying, 'I just didn't know what to do or think or how to act. While I was the first to see it, the whole Lowell staff had been working on it for a quarter of a century. I was just lucky, that's all.'" Almost involuntarily we think of the well-known lines of Keats,

> "Then felt I like some watcher of the skies
> When a new planet swims into his ken."

Few indeed have had the opportunity of feeling that thrill; perhaps Tombaugh felt it even more than Herschel, who did not at first dream that he had found a planet; in fact, the object was called a comet for several months. I had a personal experience of this fact a few years ago. Some of Hornsby's manuscripts were sent to Greenwich for re-reduction; some sheets of them were handed to me, which contained

observations of a so-called comet, made by Hornsby in 1781 ; I looked at them for some minutes, thinking that it was a very slow-moving comet ; then it suddenly dawned on me that it was the planet Uranus.

The astronomers at the Lowell Observatory were very cautious about making an announcement of their discovery ; there was a possibility that it might be an asteroid with abnormal eccentricity, or even a comet. However, seven weeks of observation sufficed to establish its trans-Neptunian position, and the details were given to the world by telegram and circular.

For a week or thereabouts, all accepted its planetary character. Then some astronomers, impressed by its small size and faintness, thought that the designation " comet " was more suitable. Their attitude was strengthened by the first orbit of the new body, that was issued by the Lowell Observatory ; this was a very eccentric ellipse, with a period of three thousand years and perihelion passage at the beginning of this century. Meanwhile the photographic plates of many observatories were being scanned in the hope of finding images in former years ; M. Delporte was the first to find an image on a plate taken at Uccle in 1927 January. This was followed by four images secured at Mt. Wilson in 1919, some at Yerkes in 1921 and 1927, and finally one at Königstuhl in 1914. These images have sufficed to prove that Pluto's orbit is not much more eccentric than that of Mercury ; moreover, Pluto is probably at least as large as Mars, and as there is not the smallest sign of coma, I think that most, if not all, of those who wished to reduce it to cometary rank are now willing to reinstate it among the planets.

It is of interest to note that the Mt. Wilson plates of 1919 were taken specially to search for the planet predicted by Pickering, which was in the same region as that of Lowell ; but although there were four images of the planet upon them, these were not detected until an ephemeris based upon later observations gave a hint where to look. This fact shows that it is one thing to have a faint image of a moving object upon a plate, and another thing to detect its presence there. We are the more impressed thereby as regards the close care with which our Medallist must have scrutinised the plates that he took ; there must have been hundreds, perhaps thousands, of objects as bright as Pluto upon them, the region being quite close to the Milky Way.

It must be an additional source of gratification to Mr. Tombaugh and to all the staff of the Lowell Observatory that the orbit of Pluto conforms so closely to that predicted by Lowell ; actually the agreement is a good deal closer than that between Neptune's orbit and the orbits predicted by Adams and Le Verrier. It must be admitted that there is a good deal of luck in this, for, as Lowell himself pointed out, the residuals upon which his work was based were so small that the precision of a rifle was not to be looked for, but only that of a shot-gun ; also he was not hampered by a preliminary assumption of the truth of Bode's Law ; it was this erroneous assumption that caused the orbits predicted by Adams and Le Verrier to deviate so widely from the truth.

I will now hand the medal and gift to you, Professor Fowler, asking you to transmit them to Mr. Tombaugh, together with an expression of our sincere congratulations on this brilliant success which he has achieved so early in his astronomical career. We hope that he may thereby be encouraged to persevere with renewed enthusiasm in astronomical work ; I think that we may even express a faint hope that he may in the future still further extend the boundaries of the planetary system by giving us an extra-Plutonian planet.

Election of Officers and Council.

The following Fellows were elected as Officers and Council for the ensuing year :—

President.

H. KNOX-SHAW, Esq., M.A., D.Sc., Radcliffe Observer, Oxford.

Vice-Presidents.

A. C. D. CROMMELIN, Esq., B.A., D.Sc.
JOHN JACKSON, Esq., M.A., D.Sc.
Sir JAMES JEANS, M.A., D.Sc., Sc.D., LL.D., F.R.S.
F. J. M. STRATTON, Esq., D.S.O., O.B.E., M.A., D.L., Professor of Astrophysics, Cambridge.

Treasurer.

J. H. REYNOLDS, Esq.

Secretaries.

HERBERT DINGLE, Esq., D.Sc., Assistant Professor of Astrophysics, Imperial College of Science and Technology, South Kensington.
W. M. SMART, Esq., M.A., D.Sc., John Couch Adams Astronomer, Cambridge.

Foreign Secretary.

ALFRED FOWLER, Esq., D.Sc., F.R.S., Yarrow Research Professor of the Royal Society, Imperial College of Science and Technology, South Kensington.

Council.

J. A. CARROLL, Esq., M.A., Ph.D., Professor of Natural Philosophy, Aberdeen.
S. CHAPMAN, Esq., M.A., D.Sc., F.R.S., Chief Professor of Mathematics, Imperial College of Science and Technology, South Kensington.
L. J. COMRIE, Esq., M.A., Ph.D., Superintendent of the *Nautical Almanac*.
Sir FRANK DYSON, K.B.E., M.A., D.Sc., LL.D., F.R.S., Astronomer Royal.
W. M. H. GREAVES, Esq., M.A.
F. J. HARGREAVES, Esq.
Major A. E. LEVIN, T.D.
Major W. J. S. LOCKYER, M.A., Ph.D., Director of the Norman Lockyer Observatory.
E. A. MILNE, Esq., M.B.E., M.A., M.Sc., F.R.S., Rouse Ball Professor of Mathematics, Oxford.
H. F. NEWALL, Esq., M.A., D.Sc., F.R.S.
B. M. PEEK, Esq., M.A.
Sir G. T. WALKER, C.S.I., M.A., Sc.D., F.R.S., Professor of Meteorology, Imperial College of Science and Technology, South Kensington.